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THE GEORGE C. MARSHALL SPACE FLIGHT CENTER
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HUNTSVILLE, ALABAMA 35812

By:

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ON BEHALF OF:

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(IGCRE is *jointly operated by the University of Alabama in Huntsville and Universities Space Research Association*)

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Educational Outreach

Dr. Gregory N. Cox, Research Scientist, UAH

Dr. Gregory N. Cox, began performing research on this project, September 1, 1993. He is currently on foreign travel and was unable to submit a report. However, a summary of his activities for both reporting periods will be included in the next Semi-Annual report.

Geophysical Modeling and Processes

Dr. John Christy, Assistant Professor, UAH

Dr. Charles Cohen, Research Associate, USRA

Dr. Charles Laymon, Associate Scientist, USRA

Dr. Huei-Iin Lu, Associate Scientist, USRA

Ms. Jayanthi Srikishen, Research Associate, USRA

Dr. Shouping Wang, Associate Scientist, USRA

Dr. John Christy, began support on this project September 1, 1993, to continue efforts in the area of identifying systematic biases between NOAA polar orbiters as they related to the stability of long-term trends in temperature. Data are continued to be offered to NOAA and researchers around the world in a timely fashion for assessment of global climate change issues.

In November 1993, Dr. Christy briefed Robert Watson of the White House Office of Science Advisor on pending publication of the Nature paper and how this might affect public policy.

Mr. John Brewer, Graduate Research Assistant began working in the Atmospheric Science Program course study this year under Dr. Christy's supervision. He has been primarily involved with the first year of courses, but has made some initial progress in utilizing the Genesis global climate mode for studies of hydrology.

Publications:

Christy, J.R. and C.-S. Yoon, 1993: Forecasting lower-tropospheric temperatures with 11-15 day lead time. *18th Climate Diagnostics Workshop*, 1-5 November, Boulder, CO.

Christy, J.R., and R.T. McNider, 1993: Detecting global warming using a precise but short (15-years) satellite data set. *18th Climate Diagnostics Workshop*, 1-5 November, Boulder, CO.

Christy, J.R., and R.W. Spencer, 1994: Reduction of noise in MSU lower tropospheric daily temperatures. *J. Climate* (in preparation).

Karl, T.R., R.W. Knight, and Christy, J.R., 1994: Global and hemispheric temperature trends: uncertainties related to inadequate spatial sampling. *J. Climate* (in press).

Christy, J.R., and S.J. Drouilhet, 1994: Variability in daily, zonal mean lower-stratospheric temperatures. *J. Climate*, 7, 106-120.

Christy, J.R., and R.T. McNider, 1994: Satellite greenhouse signal. *Nature*, 367, 325.

Christy, J.R., and J.J. Hnilo, 1994: Comparison of GCM and MSU temperatures for the AMIP experiment (1979-1988). *Proc. 6th Conference on Climate Variations*, 24-28 January, Nashville, TN. 189-192.

Christy, J.R., and R.T. McNider, 1994: Detecting global warming using a precise but short (15-years) satellite data set. *Proc. 5th Symposium on Global Change*, 24-28 January, Nashville, TN. 166-171.

Christy, J.R., and J.D. Goodridge, 1994: Precision global temperatures from satellites. *Atmos. Env.* (in press).

Dr. Charles Cohen, began research on this project September 15, 1993. He made several two-dimensional simulations of deep convection with the Regional Atmospheric Modeling System (RAMS) model with the aim of determining whether the vertical motion in clouds can be diagnosed from a satellite image of the precipitating ice. The SSM/I satellite measures the total amount of ice in a vertical sounding of the atmosphere. To enable a general conclusion to be

made about whether vertical motion in clouds can be computed from the satellite data, the simulations must be made in a variety of different environments.

All of the simulations began from a horizontally homogeneous initialization with a single sounding. When the sounding was from the GARP (Global Atmospheric Research Program) Atlantic Tropical Experiment (GATE) or from the Australian Monsoon Experiment (AMEX), the lower boundary of the model was entirely ocean at a fixed temperature, and the simulations worked very well, with long-lasting convection. When the model was initialized with a sounding taken in Oklahoma during the Preliminary Regional Experiment for Stormscale Operational and Research Meteorology (PRESTORM), initial simulations were done without surface fluxes, because to include surface fluxes over land would require the use of a soil model with several layers, and the inclusion of radiation, both of which would make the simulation more expensive and more complicated. Deep convection developed in the model, but it dissipated after just a few hours, despite the unusually large conditional instability in the initial sounding. After a few hours, vertical diffusion had greatly reduced the instability, even in areas remote from the convection. This large diffusion is normally included because it is physically realistic; in convective boundary layers, rising thermals, which obtain their energy from surface fluxes, mix the air vertically. Since this simulation did not include surface fluxes, the magnitude of the eddy diffusion was greatly reduced, resulting in long-lasting convection.

The various sources and sinks of precipitating ice in the model were computed, and compared to the momentum in clouds with ice. The PRESTORM simulation differed from the others in that the largest single source of precipitating ice was the process of setting negative values to zero. In the GATE and AMEX simulations, this process produced a substantial, but relatively smaller, source of ice. In the RAMS microphysics parameterization, the total of all the sources and sinks of a particular particle type cannot deplete more of the particle in each time step than exists at the start of the time step. However, negative values can result when the microphysics tendencies are added to the tendencies due to other processes. In addition, as in many other numerical models, finite differencing methods applied to advection can produce negative values. In this simulation the negative values were entirely a result of the advection calculation. Without rewriting a substantial portion of the model, the only way to reduce the production of negative values was to increase the magnitude of the eddy diffusion, which required the inclusion of a multi-layer soil model and radiation. With these changes, the simulations are successful, with long-lasting convection and a relatively small source of ice from setting negative values to zero.

Additional experiments were done with a sounding from the Convection and Precipitation/ Electrification Experiment (CaPE), which was held in Florida. Instead of initiating convection with an artificial disturbance, as was done in the other simulations, convection in this simulation was generated by a realistic sea breeze circulation.

Results from all of these experiments indicate that the ice content in kg, divided by three, is approximately equal to the cloud momentum, in kg m s^{-1}, averaged over the previous 76 minutes. However, there are large variations from this average result, depending on the type of ice particles that are present. When hail or graupel forms, it falls out quickly, resulting in a relatively large value of time-averaged cloud momentum compared with the ice content. Hail and graupel form

and grow by freezing and riming, which is quickly followed by melting as the ice falls out of the cloud. The other ice species, snow and aggregates, form and grow by deposition and by conversion from smaller pristine crystals, and have small fall velocities, which allow them to stay aloft for long periods of time.

Any relationship between vertical motion and ice content is true only when the entire model domain is considered. There is often no correlation between ice and cloud momentum for portions of the domain, because horizontal advection can move ice into or out of a section of the domain faster than it is formed locally. In order to compute vertical motion from satellite measurements of ice, some information about the fall velocity of the ice would need to be known, and the cloud system as a whole would need to be examined.

Some corrections were made to the microphysics parameterization in the Limited Area Mesoscale Predictions System (LAMPS) model. Using the past values, instead of the current values, of the prognostic variables to compute tendencies eliminated the isolated points with a zero moisture content within clouds. In addition, the difference between the warm-rain microphysics in the old and the new versions of the LAMPS model was determined to be entirely a result of different equations for terminal fall velocity of rain. As a result, a third equation, which is a better fit to the observations of fall velocity, is being inserted in the model.

Work has begun on computing a water and ice budget for the LAMPS model.

Publications:

Cohen, C., 1993: A comparison of two cumulus parameterizations in mesoscale numerical simulations of moving cloud lines. *Proc. 17th Conference on Severe Local Storms*. 4-8 October, St. Louis, MO. 520-523.

Dr. Charles Laymon began performing research February 1, 1994, in the following areas:

CaPE Project: Expanding on earlier investigations of the rainfall-runoff relationship for the CaPE (Convective and Precipitation/ Electrification) study area, Dr. Laymon completed an initial estimate of ET for the CaPE study area using a water balance method. The cumulative daily mean stream discharge and change in groundwater storage over a large portion of the CaPE study area was subtracted from the total daily rainfall obtained from a gridded raingage dataset. These initial results compare remarkably well with pan evaporation data and modeled ET using an aggregate of portable meteorological station data.

Soils data obtained from the USDA Soil Conservation Service in digital form were converted and ingested into our Intergraph Image Station. The data structure of the acquired data was inconsistent with Intergraph's data structure, therefore requiring development of an unusual data manipulation scheme to convert the graphic information into graphic elements within the GIS. Another scheme was developed to populate the relational database tables with the associated attribute information. Effort is now focused on accessing the database information and

manipulating it from vector to raster format to output gridded ASCII arrays for ingestion by a surface model being developed.

Goshute Project: AVHRR data for a NASA RTOP was obtained from the Louisiana State Univ., Computer Mapping Laboratory, for the Goshute (Nevada) project. Difficulties resulting in data format compatibility were encountered. Intergraph Corp. stepped in to develop a specific utility for us to read the data. An AVHRR Land Cover data set for the conterminous US was ordered from the USGS for use in georegistering these raw AVHRR images.

SPOT data acquired from SPOT Image Corp. and Landsat TM data from Utah State University were converted for use in the Intergraph Image Station and georegistered. Normalized Difference Vegetation Indicies (NDVI) were computed for these datasets. Another Landsat scene was ordered through the NASA Global Change Research Program agreement with EOSAT Corp. to coincide with the SPOT scene.

Earthbase: A new project was initiated to develop an Earthbase at the Huntsville Botanical Gardens. The facility will be include meteorological and hydrological instrumentation to demonstrate ground truth activities in connection with remote sensing research on Global Change. Four middle schools in the area will also receive modest instrumentation. The Earthbases have been designed, a site has been selected at the Gardens and procurement of instrumentation has been initiated.

Problems encountered are those to be expected with transfer-ring data of different formats between different systems and different software packages. They are often difficult and time consuming to resolve. Other delays were encountered due to bugs Dr. Laymon discovered in Intergraph software.

The surface hydrologic model is currently undergoing major changes which will continue during the next reporting period. In addition, initial runs will be conducted and debugging the program. Further developments in the use of the Soil Conservation Service soil data as model input will be performed. Dr. Laymon will complete the georegistration of the AVHRR scenes, and the new Landsat scene. He will also be acquiring the surface measurement data from the Goshute Valley, Nevada for use in multispectral analysis of the AVHRR, SPOT and Landsat data for hydrologic processes. Instrumentation will be installed and tested at the Earthbases.

Publications:

Rickmann, D., K. Butler, and C. Laymon, 1993: Survey of geographic information systems applications for the Earth Science and Applications Division. NASA Technical Memorandum.

Dr. Huei-Iin Lu, began supporting this project September 15, 1993. During this reporting period he published two conference proceedings which are listed below chronologically. Dr. Lu plans to continue working on the Life Cycles of Extratropical Cyclones (SLCEC) conference paper and a journal paper on the amplitude vacillation.

Publications:

Lu, Huei-Iin, T.L. Miller, and F. Leslie, 1993: Numerical simulations for geophysical fluid flow experiments. *Proc. 1st Pacific International Conference on Aerospace Science and Technology (PICAST).* 6-9 December, Tainan, Taiwan (in press).

Lu, Huei-Iin, T.L. Miller, 1993: Intransitivities in numerical climate prediction. *Proc. 6th Conference on Climate Variations.* 23-28 January, Nashville, TN. 16-19.

Lu, Huei-Iin, 1993: A numerical study of wavenumber selection in the baroclinic annulus flow system. *Geophysical and Astrophysical Fluid Dynamics* (in press).

Lu, Huei-Iin, 1993: Characteristics of annulus baroclinic wave structure during and amplitude vacillation. *International Symposium on the Life Cycles of Extratropical Cyclones (SLCEC)* (in press).

Ms. Jayanthi Srikishen, began performing the following activities January 1, 1994:

Numerical Models: Worked with Drs. Fitzjarrald and Robertson on the GENESIS on the CRAY at MSFC and Alabama Supercomputer. Benchmark runs and evaluation of C-90 at Alabama Supercomputer for Dr. Robertson.

Visualization: Used the graphics package GRADS for visualizing the model output.

User Interface: Assisted the scientists with their problems in computing.

Dr. Shouping Wang, performed research entitled, "Modeling Marine Boundary Layer Clouds," beginning September 15, 1993.

For past 6 months, his major focus has been on two subjects: to understand how the GENESIS climate model simulates low-level stratiform clouds; to implement a prognostic cloud scheme in his boundary layer model and to use satellite data to constrain the model to derive boundary layer structures during the period of Atlantic Stratocumulus Transformation Experiment (ASTEX).

The Genesis Model: Considerable effort was required to understand the convection scheme used in the model and to run the model with and without Slingo's stability dependent stratus cloud scheme. Results showed that although the model gives the right locations of maximum cloud fraction, it results in excessive low-level clouds, particularly in tropics. In the trade-wind region where the cloud fraction is observed to be about 0.1, the simulated fraction is about 0.3-0.4. It appears that lack of cloud-top entrainment and effective shallow convection contribute to the problem. The simulated seasonal variations were also studied. The model gives much less seasonal change in albedo and less cloud fraction over the eastern North Pacific and the area off the west coast of Peru than that derived from observations. Dr. Wang made a 5-year run based on the 1992 sea surface temperature. The purpose of this run was to compare the model results

with those from ASTEX observations. He submitted an abstract on this work to the American Geophysical Union Spring 1994 Meeting.

The Regional Boundary Layer Model: Dr. Wang implemented a prognostic scheme of cloud liquid water and cloud fraction in the model based on that developed by Tiedtke (1993). It was found that the scheme results in realistic cloud fraction and liquid water content in downstream simulations with a one-dimensional version of the model. He included the satellite data of cloud-top heights and cloud fraction in the predictive equations of these variables as nudging terms. Thus, the variables from the model are forced toward the observed values. Then the model gives the boundary layer structure which is constrained by the satellite data. Satisfactory results were not obtained from the regional model. He submitted an abstract on this work to the "Second International Conference on Air-Sea Interaction," September 22-27, 1994.

Dr. Wang plans to perform the following research activities during the next reporting period

- Study the performance of the GENESIS model in simulating low-level clouds;
- Incorporate satellite data to the boundary layer model to retrieve the boundary layer structure;
- Use the plume model used in the GENESIS to simulate the stratocumulus boundary layer to evaluate the model and possibly improve the model.

Publications:

Wang, S.Q., 1993: Roles of drizzle in a one-dimensional third-order turbulence closure model of the nocturnal stratus-topped marine boundary layer. Accepted by the *J. Atmos. Sci.*

Wang, S.Q., and P. Minnis, 1994: Deriving boundary layer structure with a satellite-data constrained boundary layer model. Submitted to *2nd International Conference on Air-Sea Interaction and on Meteorology and Oceanography of the Coast Zone*, 22-27 September, Lisbon, Portugal.

Land Surface Processes and Atmospheric Interactions

Mr. David Bowdle, Research Scientist, UAH

Dr. Bill Crosson, Research Associate, USRA

Mr. Dean Cutten, Research Scientist, UAH

Dr. Dick McNider, Associate Professor, UAH

Dr. Ravikumar Raghavan, Research Associate, USRA

Dr. Aaron Song, Senior Research Associate, UAH

Mr. David Bowdle, began research September 1, 1993, on the Doppler lidar for this project. The activities performed during this reporting period concentrated on scientific issues that provided important inputs to the restructuring of the Laser Atmospheric Wind Sounder (LAWS) and GLObal Backscatter Experiment (GLOBE) programs.

GLOBE Science Coordination: Responsibilities involved informally coordinating data processing, analysis, and publications within the external GLOBE Science Working Group (SWG) and the internal MSFC Aerosol/Lidar Group; hosting GLOBE investigator visits to MSFC; distributing GLOBE results to the science and aerospace communities; and planning the next GLOBE SWG meeting. Mr. Bowdle also began a journal paper on the GLOBE program and prepared a draft GLOBE "white paper," consisting of recommendations to NASA Headquarters (HQ) for GLOBE research activities during the next few years.

LAWS Science Team Membership: Contributed a GLOBE section to a journal paper on LAWS. He attended the winter LAWS meeting and gave a presentation on GLOBE. Mr. Bowdle has been an Associate Member of an official EOS LAWS Science Team since January 1989 through December 1993. In December, LAWS was officially de-selected from EOS. In February 1994, he became a full member of an ad hoc LAWS Science Team.

LAWS Mission Development: Developed estimates of aerosol backscatter at the 2.1 micron wavelength (in conjunction with Dr. Vandana Srivastava, IGCRE), for inputs to NASA's systems study on a 2 micron version of LAWS, and presented the results at NASA's 2 micron technology review. He also conducted a parametric assessment of various Doppler lidar design concepts for LAWS. This task included attending a short course on coherent Doppler lidar, reviewing incoherent Doppler lidar technology at the University of Michigan, and assessing the impact of backscatter magnitude and backscatter wavelength dependence on various LAWS design concepts. He evaluated the impact of these results on MSFC plans for a LAWS science demonstration mission, presented the results in numerous internal meetings at MSFC, and began to incorporate the results in a comprehensive journal paper.

GLOBE Analysis and Modeling: Routinely coordinates and reviews internal and external GLOBE data analysis and modeling, with particular attention to quality control and internal/external consistency. He used GLOBE results provided by Dr. Dean Cutten (IGCRE) and Dr. Srivastava to develop empirical global backscatter models for wavelength combinations of 9.1 microns versus 0.53, 1.06, and 1.54 microns. These empirical models validated IGCRE's earlier theoretical global backscatter models for 9.1 microns versus 2.1 microns.

Reviews: Reviewed two proposals for NASA's Atmospheric Effects of Aviation Program/Subsonic ASSessment (AEAP/SASS) and one proposal for NASA's Tropical Rainfall Measurement Mission (TRMM).

Reviewed draft plans for an Optical Atmospheric Measurements (OAM) program by NASA's Dryden Flight Research Facility. This prospective program is designed to develop the scientific and technological basis for operational Doppler lidar systems for high-altitude airspeed and turbulence measurements on a wide variety of commercial, military, and high-performance test

aircraft. The OAM program relies heavily on GLOBE results to provide initial inputs to prototype lidar design studies.

Activities to be performed during the next reporting period will concentrate on a series of journal papers, technical reports, and the following activities:

GLOBE Science Coordination: Coordinate the Eleventh Meeting of the GLOBE Science Working Group, scheduled for Williamsburg, Virginia, in early May; present several papers; and publish the proceedings. Complete the GLOBE journal paper, the GLOBE "white paper," and a technical report on the GLOBE survey missions. Prepare a journal paper on GLOBE field programs, a technical report on the GLOBE database (in conjunction with Dr. Cutten), and a draft GLOBE III operations plan.

LAWS Science Team Membership: Participate in the next LAWS Science Team meeting, tentatively scheduled for July in Seattle, Washington.

LAWS Mission Development: Assist MSFC in developing a LAWS science demonstration mission. Complete the paper on parametric analysis of Doppler lidars.

GLOBE Analysis and Modeling: Prepare a series of papers on GLOBE backscatter wavelength dependence, in conjunction with Dr. Srivastava and Dr. Cutten. Begin preparing a series of papers on empirical global backscatter models, with particular emphasis on the middle and upper tropospheric background aerosol system.

OAM Science Team Membership: Serve on the OAM Technical Steering Committee, pending approval of an OAM proposal to NASA HQ. Advise OAM about tropospheric aerosol backscatter properties and their effects on airborne Doppler lidar velocity measurements.

Publications:

Srivastava, V., A.D. Clarke, D.R. Cutten, D.A. Bowdle, and M.A. Jarzembski, 1993: Wavelength dependent aerosol backscatter calculations from modeled and measured microphysics compared to direct lidar measurements. *12th American Association of Aerosol Research 1993 Annual Meeting*. 11-15 October, Oak Brook, IL.

Cutten, D., R. Pueschel, J. Rothermel, A.D. Clark, and D.A. Bowdle, 1993: Comparison of measured and modeled scattering parameters for tropospheric aerosols. *12th American Association for Aerosol Research 1993 Annual Meeting*. 11-15 October, Oak Brook, IL.

Bowdle, D.A., D.R. Cutten, V. Srivastava, E.W. McCaul, J. Rothermel, and M. Jarzembski, 1993: Estimating aerosol backscatter coefficients at 2 microns using GLOBE measurement and modeling results. Presented at *NASA's Third Two Micron Solid-State Laser Technology Review*, Washington D.C., 8-9 November.

Bowdle, D.A., D.R. Cutten, V. Srivastava, and E.W. McCaul, Jr., 1994: The GLObal backscatter experiment (GLOBE): status, results, and plans. Presented at the *LAWS Science Team Meeting*, Clearwater, FL. 1-3 February.

Bowdle, D.A., and G.D. Emmitt, 1994: Report on LAWS science team member's visit to the University of Michigan. IGCRE, Huntsville, AL, and SWA, Charlottesville, VA. (in final review - to be submitted to the LAWS Science Team).

Bowdle, D.A., 1994: Recommendations for multi-agency GLOBE-related research in the mid-1990's. IGCRE, Huntsville, AL (in final review, to be submitted to NASA HQ).

Bowdle, D.A., 1994: Space-based doppler lidar wind measurements: A parametric systems study of selected design concepts. *Appl. Opt.* (in preparation).

Bowdle, D.A., 1994: The GLObal backscatter experiment (GLOBE). *Bull. Amer. Meteor. Soc.* (in preparation).

Bowdle, D.A., J. Rothermel, and S.F. Williams, 1994: GLObal Backscatter Experiment (GLOBE) First and Second Survey Mission Summary Document. NASA MSFC, Huntsville, AL (in preparation).

Bowdle, D.A., and D.R. Cutten, 1994: The GLObal backscatter experiment (GLOBE) database. IGCRE, Huntsville, AL (in preparation).

Dr. Bill Crosson, began working on this project beginning February 1, 1994. His activities for this period have been directed toward modeling surface energy and hydrologic processes utilizing data collected during the Convection and Precipitation /Electrification Experiment (CaPE) held in east central Florida in 1991. The objectives of this project are to establish and apply methodologies for the diagnosis of land and atmospheric water budget components for the CaPE region (approximately 25000 km^2). The underlying philosophy guiding this study is that these techniques can be applied on scales consistent with GEWEX (Global Energy and Water cycle Experiment) Continental International Project (GCIP) activities such as the CART ARM experiment and ultimately the Mississippi basin. The surface energy and water flux component of this investigation is being carried out using a land surface model based on the Biosphere-Atmosphere Transfer Scheme (BATS), in conjunction with data from a wide array of measurement systems. The model has been tested using data from the two Florida State University flux sites. These stations were used because of the availability of model input variables-wind, temperature, humidity, pressure, precipitation and solar and longwave downwelling radiation, as well as flux measurements necessary for model validation. Results from these simulations indicate that the model, using soil and vegetation parameter values appropriate for the local conditions, is capable of accurately estimating surface energy and moisture fluxes.

Model simulations have been performed for each of the 38 PAM sites within our study area, producing initial estimates of areal heat and moisture fluxes. Thirteen of the PAM stations

measured incident shortwave radiation; four of these also collected reflected shortwave, emitted longwave and net radiation, and soil temperatures. Model sensitivity to radiation input is currently being tested using a variety of methods for specifying solar and longwave fluxes using the point measurements. For example, what is the impact on model-diagnosed fluxes of using spatially uniform radiative input, as compared with values measured at each site?

A more sophisticated modeling scheme for estimating areal fluxes for the CaPE domain has been designed. This new model, the Simulator for Hydrology and Energy Exchange at the Land Surface (SHEELS) is a gridded model which incorporates BATS, geographic information (landcover classes and soil properties), and statistical distributions of surface properties (such as leaf area index, albedo and fractional vegetation cover) based on high-resolution remotely sensed data. Distributions of NDVI and spectral albedo have been derived from 20 m resolution SPOT imagery for each of the 18 land cover classes in the study area.

In order to diagnose daily areal mean heat and moisture fluxes, Dr. Crosson will run SHEELS over the CaPE domain; each grid cell will be treated as a mixture of landcover types. Meteorological forcing for the model will be supplied by measurements from ground based stations and by rainfall derived from raingages and radar. To add further realism to the model, the statistical distributions of surface properties within each landcover 'patch' will be represented via a discrete probability density function inferred from the observed distributions of NDVI and albedo. Scale issues will be addressed with a series of model runs in which the resolution of remotely sensed data, used to establish the nature of surface variability, is degraded. Preliminary analyses have shown that degradation of SPOT data from 20 m up to 1 km resolution (simulating AVHRR footprints) results in large changes in both mean and variance of surface properties.

SHEELS will continue to undergo modifications to improve the representation of surface and sub-surface water routing. Appropriate algorithms will be integrated into the model, and digital elevation data will be incorporated to drive these processes.

Publications:

McNider R.T., J.A. Song, D.M. Casey, P.J. Wetzel, W.L. Crosson, and R.M. Rabin, 1993: Toward a dynamic-thermodynamic assimilation of satellite surface temperature in numerical atmospheric models. Submitted to *Mon. Wea. Rev.*

Crosson, W.L., C.E. Duchon, R. Raghavan, and S.J. Goodman, 1994: Estimation of rainfall for hydrologic application using raingages, doppler radar and composite WSR-57 radar observations. *J. Appl. Meteor.* (in preparation).

Mr. Dean Cutten began working on this project September 1, 1993, to perform research in the following areas:

GLOBE Backscatter Calculations: Work continued on aspects of scientific applications using the GLObal Backscatter Experiment (GLOBE) data at MSFC. Most GLOBE data were obtained during Pacific Ocean Survey Missions in Fall 1989 (GLOBE I) and Spring 1990 (GLOBE II) on the NASA Ames Research Center (ARC) DC-8 aircraft.

In this period activities concentrated on deriving aerosol backscatter coefficients at 1.06 μm and 9.1 μm wavelengths using ARC Forward Scattering Spectrometer Probe (FSSP) size distribution data. Part of this analysis has involved procedures to minimize the variations of the FSSP-derived aerosol backscatter. The first step was to recalibrate the FSSP size data, accounting for multivalued bins, and average these data to 100 s periods. Each of the resulting volume distributions was then fitted by a single mode lognormal curve, which generally exhibits a pronounced peak in the size range 1-3 μm. The calculated backscatter coefficients were then smoothed temporally using a 3 point filter function to give 300 s averages. Refractive index data available at 1.06 μm and 9.1 μm wavelengths were obtained from the University of Hawaii Laser Optical Particle Counter (LOPC) data. Comparisons were done with pulsed lidar aerosol backscatter coefficient measurements made near the DC-8 aircraft, to validate the model used.

For seven of the GLOBE II flights examined so far the computed aerosol backscatter, for many parts of the flight, follows the main trends exhibited in the measured aerosol backscatter near the aircraft at 1.06 and 9.25 μm. Known inhomogenuities in the aerosol field account for some of the discrepancies. However, large fluctuations still remain for the 9.1 μm derived backscatter coefficient data. These can be traced mostly to poor count statistics in the bins larger than 1 um diameter, which do not significantly affect the 1.06 μm aerosol backscatter.

GLOBE Database Activities: Further work continued on reviewing GLOBE data quality for certain datasets in conjunction with the Principal Investigators (PI's) responsible for these data. Further beta copies of the data visualization/analysis program LINKWINDS (being developed by Jet Propulsion Laboratory (JPL)) were received during this period for evaluation. This program has been used as the main tool for examining and analyzing much of the data in the GLOBE database.

GLOBE Data Archival Software: Continued to monitor the work being done by Simpson Weather Associates (SWA) who are refining the code written earlier to archive the GLOBE data in the Hierarchival Data Format (HDF). This software will provide a standardized means of reading the various datasets which GLOBE PI's provided using their own format. It will also allow a means of implementing a basic data security scheme to allow dataset integrity to be checked.

Mr. Cutten plans to continue working in the following areas:

1) The FSSP-derived aerosol backscatter coefficient analysis will be finalized and a paper initialized describing the results.

2) Develop algorithms to minimize instrument artifact effects observed in the Goddard Space Flight Center (GSFC) 1.06 μm and JPL 9.25 μm pulsed lidar datasets.

3) Redo the lidar wavelength scatterplot analysis using the revised data.

Publications:

Cutten D.R., R. Pueschel, J. Rothermel, A.D. Clarke, and D.A. Bowdle, 1993: Comparison of measured and modeled scattering parameters for tropospheric aerosols. Presented at *12th Annual Meeting American Association for Aerosol Research*, Oak Brook, IL.

Srivastava V., A.D. Clarke, D.R. Cutten, D.A. Bowdle, and M.A. Jarembski, 1993: Wavelength dependent aerosol backscatter calculations from modeled and measured microphysics compared with direct lidar measurements. Presented at *12th Annual Meeting American Association for Aerosol Research*, Oak Brook, IL.

Bowdle, D.A., D.R. Cutten, V. Srivastava, E.W. McCaul, J. Rothermel, and M. Jarzembski, 1993: Estimating aerosol backscatter coefficients at 2 microns using GLOBE measurement and modeling results. Presented at *NASA's Third Two Micron Solid-State Laser Technology Review*, Washington, D.C. 8-9 November.

Bowdle, D.A., D.R. Cutten, V. Srivastava, and E.W. McCaul, 1994: The GLObal backscatter experiment (GLOBE): status, results, and plans. Presented at the *LAWS Science Team Meeting*, Clearwater, FL. 1-3 February.

Srivastava V., A.D. Clarke, M.A. Jarzembski, D.R. Cutten, and D.A. Bowdle, 1994: Effect of microphysics on aerosol backscatter: Comparison of modeling and measurements obtained during NASA's globe mission. To be presented at the *4th International Aerosol Conference*, Los Angeles, CA. 28 August - 2 September.

Bowdle, D.A., and D.R. Cutten, 1994: The GLObal backscatter experiment (GLOBE) database. IGCRE, Huntsville, AL (in preparation).

Dr. Ravikumar Raghavan, began working on this project beginning February 1, 1994, to perform the following activities:

WSI-WetNet Marshall DAAC Operations: Algorithm design and implementation for processing the real-time U.S.

Development and implementation of software to create radar Browse products on the DAAC.

National Composite Radar Data: This data is being received at the Distributed Active Archive Center (DAAC) via satellite link. The WSI radar data is received via satellite every 5 and 15 minutes and will be stored on the Marshall DAAC.

The U.S. National radar composite image is then converted to a U.S. National Precipitation (Rainfall) image. This image will be stored in the DAAC and will be made available as a browse product. The rainfall image will also be made available for distribution to the science community. Furthermore, the precipitation image will be made available on the LAN for viewing. Rigorous testing of the algorithm is being conducted in a modular mode and final implementation is being incorporated.

Thunderstorm Electrification Studies: Ongoing analysis of multiparameter radar data from the CaPE field campaign to study the microphysical characteristics, kinematics and morphology of clouds as well as the various processes that lead to the electrification and the subsequent production of lightning.

He also procured and installed current versions of the NCAR graphics library and other related volumetric radar processing software on the SUN/SPARC workstation.

Dr. Ravikumar encountered WSI data problems during January. The ingested data was getting corrupted and has taken nearly two months to solve. However, it now appears that this error has been overcome.

During the next reporting period, Dr. Ravikumar will test the developed WSI software. After the test period is complete, the software will run under DAAC operations. He also plans to continue examination and analysis of CaPE data in the context of Thunderstorm Electrification studies.

Publications:

Raghavan, R., J. Turk, and J. Vivekanandan, 1994: Investigation of the vertical profiles of linear depolarization ratio and reflectivity at S, X and K band wavelengths. Submitted to *1994 International Geoscience and Remote Sensing Symposium* (IGARSS '94). Pasadena, CA. 8-12 August.

Zrnic, D.S., R. Raghavan, and V. Chandrasekar, 1994: Observations of co-polar correlation coefficient through a bright band at vertical incidence. *J. Appl. Meteor.*, **33**, 45-52.

Raghavan, R., and V. Chandrasekar, 1994: Self consistent assessment of the area time integral (ATI) technique for rainfall estimates using multiparameter radar, Revised manuscript submitted based on recommendation by reviewers, Special Issue-*J. Appl. Meteor.*

Crosson, W.L., C.E. Duchon, R. Raghavan, and S.J. Goodman, 1994: Estimation of rainfall for hydrologic application using raingages, doppler radar and composite WSR-57 radar observations. *J. Appl. Meteor.* (in preparation).

Dr. Dick McNider & Dr. J. Aaron Song, began working on this project September 1, 1993. During the reporting period they has derived an assimilation technique in which satellite observed surface skin temperature data are used in a model surface energy budget so that the predicted rate of surface temperature change in the model more closely agrees with the satellite observation. Both the visible and infrared GOES satellite data are used in the assimilation. More detailed discussion on the assimilation technique is included in McNider et. al. (1993), while the related satellite insulation assimilation is included in McNider et. al. (1994). Preliminary model verifications of a selected case using the observation of Rabin et. al. (1990) shows that the technique appears to correctly adjust the model response to agree better with observation.

In the aforementioned model simulations incorporating the assimilation technique, only "clear sky" situations were chosen. When cumulus clouds pop out, even though there is negligible large scale disturbance, it would be much more difficult to perform the assimilation technique. Unfortunately, interesting weather almost always involves clouds.

An extended application of the aforementioned assimilation technique has lately been performed using the observation of COHMEX (Williams et. al., 1987), which will be discussed in more details in Song et. al. (1994) as well as in the next semi-annual report.

References:

Rabin, R.M., S. Stadler, P.J. Wetzel, D.J. Stensurd, and M. Gregory, 1990: Observed effects of landscape variability on convective clouds. *Bull. Amer. Meteor. Soc.*, 71, 272-280.

Publications:

McNider R.T., J.A. Song, D.M. Casey, P.J. Wetzel, W.L. Crosson, and R.M. Rabin, 1993: Toward a dynamic-thermodynamic assimilation of satellite surface temperature in numerical atmospheric models. Submitted to *Mon. Wea. Rev.*

McNider, R.T., J.A. Song, D.M. Casey, P.J. Wetzel, W. Crosson, and R.M. Rabin, 1993: Toward a dynamic-thermodynamic assimilation of satellite surface temperature in numerical atmospheric models. Submitted to *Mon. Wea. Rev.*

Christy, J.R., and R.T. McNider, 1993: Detecting global warming using a precise but short (15-years) satellite data set. *18th Climate Diagnostics Workshop*, 1-5 November, Boulder, CO.

McNider R.T., J.A. Song, and S.Q. Kidder, 1994: Assimilation of satellite derived insolation into regional scale models. Submitted to *International J. Remote Sensing*.

Song J.A., R.T. McNider, S.Q. Kidder, and D.M. Casey, 1994: A regional-scale pre-convective simulation incorporating a satellite skin temperature assimilation. To be submitted to *J. Appl. Meteor*.

Christy, J.R. and R.T. McNider, 1994: Satellite greenhouse signal. *Nature*, 367, 325.

Christy, J.R., and R.T. McNider, 1994: Detecting global warming using a precise but short (15-years) satellite data set. *Proc. 5th Symposium on Global Change*, 24-28 January, Nashville, TN. 166-171.

Remote Sensing Technology and Geophysical Retrievals

Mr. Dennis Buechler, Senior Research Associate, UAH

Dr. Stanley Kidder, Associate Professor, UAH

Dr. Kevin Knupp, Assistant Professor, UAH

Dr. Doug Mach, Research Scientist, UAH

Dr. Eugene W. McCaul, Associate Scientist, USRA

Mr. Michael Stewart, Senior Research Engineer, UAH

Mr. Dennis Buechler, began supporting this project September 1, 1993, to perform research in the following areas:

LIS Simulation Study: This study investigates the effect of satellite sampling error of monthly lightning estimates due to the intermittent nature of the satellite observations. Based on cloud-to-ground lightning data in the vicinity of Huntsville. AL, this error will be on the order of 35-40%. A first draft of a paper to be submitted for publication is in the final stages of preparation. Additional computations needed to finish the draft were performed. The paper will be completed and submitted during the next reporting period.

Lightning/Precipitation Study: The purpose of this task is to develop an algorithm whereby lightning flash observations can be used to estimate convective rainfall. A simple relationship was developed using data over Florida on August 12-13, 1991. The rainfall estimated from the lightning during the period closely matched the radar derived convective rainfall both in amounts, pattern, and spatial coverage.

During the next reporting period, a better estimate of rainfall from radar and lightning data, is anticipated to be obtained perhaps by employing a matching probability distribution approach. The current results will be written and prepared for a conference.

Geolocate OTD Pixels: The OTD (Optical Transient Detector) is an instrument designed to detect optical pulses from lightning. This instrument is scheduled for launch in June 1994. The location of the lightning pulses detected by OTD need to be determined with respect to the earth (i.e. latitude and longitude). Work began with a system called SPICE (Spacecraft, Planet, Instrument, Camera, Events) which contains subroutines that can be used to geolocate pixels in the OTD array. Collaboration took place with Bill Taber of JPL (Jet Propulsion Laboratory) who helped develop SPICE, November 16, 1993; at the 3rd NASA EOS (Earth Observing System)/Pathfinder Interuse. A program to geolocate OTD lightning using SPICE or other means will be written during the next reporting period.

Publications:

Buechler, D.E., 1993: Preliminary investigation of using lightning data as an indicator of convective precipitation. *American Geophysical Union, Fall Meeting.* 6-12 December. San Francisco, CA. 153.

Dr. Stanley Kidder, began working on this project September 1, 1993, and continued working on two scientific tasks which are described below:

The first is a project on the effects of cloud shading on circulation in the Texas panhandle. Dr. Kidder along with, Drs. Dick McNider, and Aaron Song simulated a case on 24-25 April 1982. His part in the research was the radiation algorithm with which GOES brightness counts were converted to absorbed solar radiation at the surface, which was then assimilated into a mesoscale

model. This work resulted in a paper being submitted for publication during the next reporting period.

The second project involves trying to estimate surface pressure over the ocean using the MSU data set of Drs. Spencer and Christy. Surface pressure has never been successfully measured by satellites except in storms. Dr. Kidder believes that the monthly averaged MSU data is accurate enough to give good estimates of the sea level pressure. The problem is to find the right algorithm. Dr. Kidder will continue this work in the next six months. If successful, this work will be a fundamental advance in the ability to monitor the atmosphere from satellite platforms.

Publications:

McNider R.T., J.A. Song and S.Q. Kidder, 1994: Assimilation of satellite derived insolation into regional scale models. Submitted to *International J. of Remote Sensing.*

Song J.A., R.T. McNider, S.Q. Kidder and D.M. Casey, 1994: A regional-scale pre-convective simulation incorporating a satellite skin temperature assimilation. To be submitted to *J. Appl. Meteor.*

Dr. Kevin Knupp, began working on this project September 1, 1993. His work involves an analysis of the structure and characteristics (precipitation, kinematics, and cloud-top behavior) of a small mesoscale convective system that formed on 13 July 1986 over northern Alabama under conditions of weak wind shear and relatively unstable conditions. In general, such systems are believed to account for appreciable precipitation in subtropical regions such as the Southeast United States and Brazil. As part of a longer-term effort, this work will attempt to establish the importance of such systems on regional water and energy budgets. Specifically, this effort has entailed a final analysis and the beginning preparation of a manuscript. This MCS produced appreciable precipitation and cloud to ground lightning. Its kinematic structure, as synthesized from Doppler radar observations, closely resembled that of the larger and longer-lasting Mesoscale Convective Complex (MCC).

Dr. Knupp plans to complete a draft manuscript of the 13 July case study and submit it for publication. Another case study analysis from the same experiment will be finalized and also submitted for publication.

Publications:

Stalker, J.R., K.R. Knupp, and E.W. McCaul, Jr., 1993. A numerical and observational study of an atypical "miniature" supercell storm. *Proc. 17th Conference on Severe Local Storms.* St. Louis, MO. 191-195.

McCaul, E.W., Jr., K.R. Knupp, and W.L. Snell, 1993: Observations of tornadic storms and rainbands within hurricane Andrew's remnants. *Proc. 17th Conference on Severe Local Storms.* St. Louis, MO. 272-276.

Dr. Douglas M. Mach, began working on this project as of September 1, 1993, writing the level 0 to level 2 scientific data analysis software for the Lightning Imaging Sensor (LIS) and Optical Transient Detector (OTD) instruments. The LIS instrument will be launched on the Tropical Rainfall Measuring Mission (TRMM) satellite and the OTD will be launched on a Microsat (Orbital Sciences Corporation) sometime this summer. Each of these satellite sensors will detect optical pulses from lightning. The LIS instrument will do so from a tropical orbit while the OTD will do so from a much higher inclination orbit. The LIS instrument is an Earth Observing System (EOS) payload and so the data analysis software has to be 'EOS compliant'. Since the OTD data will also be added to the EOS archive, the analysis software for that instrument will also be EOS compliant.

Dr. Mach is the primary responsible person for the software that will analyze the lightning data from both instruments. Currently he is in the process of finalizing the quicklook display program and have made major progress towards finishing the level 1 and 2 software. The software for the OTD is due before launch (this summer) and is nearly complete. The LIS software is due by late 1995 and it is ahead of schedule.

The other project Dr. Mach is associated with is the AirBorne Field Mill (ABFM) program. The purpose of this project is to improve the expendable and shuttle lightning related to the Launch Commit Criteria (LCC) rules. Although this project is officially over, he is still working with the Kennedy Space Center (KSC) to improve the LCC rules.

During the next reporting period Dr. Mach should complete the basic software package for the OTD instrument and be able to test it on real data since the satellite is due to be launched this June. The data from the OTD will help me refine the LIS software, which is the other major task for the next six months.

Dr. Eugene W. McCaul, began supporting this project beginning October 1, 1993, to perform the following activities:

Develop a Gobal Water Budget Model: The water budget model, which is being constructed in collaboration with Dr. F. R. Robertson, will have the capability of showing the evolution of the three-dimensional fields of water vapor, clouds and precipitation, fields which are not currently well-known. The model is initialized with global meteorological analyses, from which the water substance fields are prognosed using the basic equations, surface fluxes, a cumulus parameterization, and ongoing adjustments to perceptible water as dictated by Special Sensor Microwave Imager data. Preliminary results suggest the model will be able to reproduce water substance fields that are consistent with available satellite observations.

Continue Analysis of Lidar and Meteorological Data From the Global Backscatter Experiment (GLOBE): GLOBE data analysis has continued in several directions. Additional flights from 1990 field work have been analyzed, and assistance was rendered to personnel in Dr. J. Spinhirne's group at Goddard Space Flight Center for the purposes of implementing data

visualization capability similar to ours at MSFC. Revised data will be delivered to MSFC in the near future, which will allow us to finalize our own studies for publication.

Dr. McCaul will continue on the development, testing and application of the water budget model. Work will also continue on the correction of the GLOBE data, followed by preparation of manuscripts describing final results.

Publications:

Stalker, J.R., K.R. Knupp, and E.W. McCaul, Jr., 1993: A numerical and observational study of an atypical "Miniature" supercell storm. *Proc. 17th Conference on Severe Local Storms.* St. Louis, MO. 191-195.

McCaul, E.W., Jr., K.R. Knupp, and W.L. Snell, 1993: Observations of tornadic storms and rainbands within hurricane Andrew's remnants. *Proc. 17th Conference on Severe Local Storms.* St. Louis, MO. 272-276.

Bowdle, D.A., D.R. Cutten, V. Srivastava, E.W. McCaul, J. Rothermel, and M. Jarzembski, 1993: Estimating aerosol backscatter coefficients at 2 microns using GLOBE measurement and modeling results. Presented at *NASA's Third Two Micron Solid-State Laser Technology Review*, Washington, D.C. 8-9 November.

McCaul, E.W., Jr., 1994: Observations and simulations of hurricane-spawned tornadic storms. *Tornado Symposium III.* April, 1991. 119-142.

McCaul, E.W. Jr., and F.R. Robertson, 1994: Large scale structure of water vapor and condensate over the TOGA-COARE Region. *Proc. 6th Conference on Climate Variations.* Nashville, TN. 23-28 January. J44-J45.

Bowdle, D.A., D.R. Cutten, V. Srivastava, and E.W. McCaul, Jr., 1994: The GLObal backscatter experiment (GLOBE): status, results, and plans. Presented at the *LAWS Science Team Meeting*, Clearwater, FL. 1-3 February.

Mr. Michael Stewart, began working on this project September 1, 1993. During this reporting period his accomplished the following tasks:

1) Concluded participation in the Advanced Ground-Based (Electric) Field Mill program.

2) Collaborated with Drs. Hugh Christian, Bill Koshak, and Jim Bergstrom to develop calibration methodologies and procedures for the Lightning Imaging Sensor (LIS) and the Optical Transient Detector (OTD). The latest procedures are specified in the OTD Calibration Facility Procedures Document, dated February 19, 1994.

3) Worked with the MSFC EB-Lab to improve the performance of the analog signal processing electronics in the OTD Real Time Event Processor. Estimated optical lightning detection efficiency for this spacecraft instrument was improved from 20% to 70% as a result of this work.

The lack of engineering system design supervision to coordinate the activities of the various branches at MSFC, and to ensure that system performance requirements are met, adversely impacted the quality of the science interment delivered to the OTD Calibration Facility.

Based on experience with the OTD, and in the absence of requirements specific enough, Mr. Stewart will generate a list of specifications and design requirements for the LIS analog signal processing electronics for the MSFC EB-Lab to meet. This should greatly improve the performance of the LIS instrument, as performance will be substantially verified prior to assembly of flight circuit boards and delivery to the Calibration Facility.

Publications:

Wilfong, T., L. Barnum, M. Stewart, G.E. Taylor, and P. Mulligan, 1993: The New Kennedy Space Center launch pad lightning warning system. *Proc. 17th Conference on Severe Local Storms and Conference on Atmospheric Electricity*. J52-J56.

Stewart, M.F. and L.R. Barnum, 1993: Maintenance manual for the advanced ground-based field mill instrument. Vol. 1 & 2. Marshall Space Flight Center.

Scientific Data Management and Visual Analysis

Dr. Don Moss, Senior Research Associate, UAH

Ms. C. Vada LaFontaine, Research Associate, USRA

Dr. Don Moss, continues to train DAAC operations personnel in level 1b data ingest and archival procedures. He wrote a technical document entitled, "MSFC DAAC 8mm Tape Instructions" for DAAC User Services group to be included in standard package shipped with orders on 8mm tapes. He also wrote technical document entitled, "NESDIS Level 1B SSM/I Tape Archival Procedure," a guide for DAAC operations personnel.

Precipitation Intercomparison Project 2 (PIP-2) input file production and utility software were completed. PIP-2 files were generated from Wentz and National Environmental Satellite Data and Information System (NESDIS) data and were sent to project coordinators at Florida State University for further processing. After retrieval from FSU, files were prepared and submitted for CD production. Ingest software was successfully tested on SGI Onyx system.

Software was developed for the following functions:

- Add batch mode option to daily backup program.
- Incorporate new method of background processing into full backup program.
- Find latest two-line orbital elements, reformat, add to McIDAS preprocessed one-line element file.
- Adapt orbital element conversion program to the DMSP-F8 satellite.
- Automatically rename Special Sensor Microwave/Imager (SSM/I) level 1b files transferred from
  Engineering and Analysis Data System (EADS).
- Display highest memory usage jobs in system.
- Improve SSM/I level 1b geographical filter program.
- Read SSM/I sensor count level 1b file, output antenna temperatures or brightness temperatures, satellite ID #, time, revolution #, latitudes, and longitudes.
- Adapt above program to increase precision.
- Read Fleet Numerical Oceanographic Center (FNOC) Temperature Data Record (TDR) files in
  Data Exchange Format (DEF) which have been reformatted for the Shared Processing Network (SPN).
- Analyze TDR files to determine and document data structures and detect and deal with anomalies.
- Add options to SSM/I level 1b merge program to restrict scans to specified scan numbers.
- Filter a character stream to allow text to be analyzed despite the presence of control characters.
- C subroutines to allow a WetNet Fortran program to read a TDR file and make McIDAS areas.
- Analyze TDR interscan time deviation.
- Improve level 1b scan summary by making output easier to read.
- Modify daily ingest, merge, and housekeeping programs to use new INGEST environment variable. This will make adapting to future operating system environment changes much easier, quicker, and more reliable.
- Make it easier to input data to satellite polar crossing predition program.
- Find, display, and remove files of a specified size.

- Filter log file to remove unwanted information.
- Automatically create new numbered versions of files being edited.
- Show all user processes.
- Allow WetNet program which makes global composite McIDAS SSM/I images to specify a control file name on the command line, enabling simultaneous multiple runs. Modify driver program accordingly. Also improve organization of driver program.

Dr. Moss will continue the following activities:

- Study SSM/I TDR data from NESDIS to identify and understand formatting anomalies;
- Check for anomalies in the data itself;
- Compare with data from other sources for the purpose of validation;
- Fully adapt existing WetNet software to this data source;
- Continue to monitor data ingest process; and
- Enhance current software to add flexibility and adaptability.

Publications:

Moss, D., 1994: MSFC DAAC 8mm Tape Instructions.

Moss, D., 1994: NESDIS Level 1B SSM/I Tape Archival Procedure.

Ms. C. Vada LaFontaine, began supporting this project January 1, 1994, to continue work on the WetNet project and with the MSFC DAAC. Her activity has increased with the DAAC. She worked more with the IMS team to help develop an order tracking system, and have provided input on user statistics and user profiles. Additionally Ms. LaFontaine coordinated the effort to update the MSFC data set names for use with the IMS, the GCMD and internally. There have been more DAAC orders during this period which required more time filling orders. These orders have allowed her to put together a "canned" package of documentation and utility routines for supported data set. She worked with system operations to implement monitoring of our anonymous FTP directories to allow tracking of the activity and volume transferred from this account.

The WetNet activity continue and Ms. LaFontaine has completed another WetNet newsletter and continues to answer user questions. In addition, she implemented a listserv list for the WetNet user community. This list has been used by the WetNet development team and by the WetNet scientists. The list has led to directly to new collaboration between several WetNet scientists. She also recently developed a WetNet Home Page for use with NCSA Mosaic. This page will be connected to the MSFC DAAC Home Page being developed.

Ms. LaFontaine plans to work more with the IMS development team, archive management and system operations as preparations are made for beginning the DAAC operations in July 94. She expects DAAC requests and questions to increase as the existence of the DAAC is advertised.

ACTIVITIES SPONSORED BY UAH

SUBCONTRACTS/CONSULTANTS

There were no consultants or subcontracts assigned under the University of Alabama in Huntsville during this reporting period.

TRAVEL

Dr. Don Moss attended WetNet Users' Conference in Logan, Utah, September 20-22, 1993. The purpose of the conference was to exchange information and discuss the accomplishments and future directions for the program.

Ms. Melanie McCook traveled to Washington, DC, and Wallops Island, Virginia, to collect data and information, September 26-30, 1993.

Mr. Dean Cutten traveled to Chicago, Illinois to attend and present a paper at the American Association for Aerosol Research and visit Argonne National Lab, October 10-16, 1993. He also traveled to Los Angeles, California, to visit the Link Winds Software Development Team at JPL, December 7-8, 1993.

Dr. Gregory Cox traveled to Washington, DC, to attend the LANDSAT Education Workshop at NASA Headquarters, November 7-9, 1993. He returned to Washington, January 18-20, 1994, to meet with NASA Education Division Representatives at NASA Hdqtrs. regarding LANDSAT Education Program.

Dr. David Bowdle traveled from November 6-9, 1993, to Washington D.C., to participate in NASA's Third Two Micron Solid-State Laser Technology Review. During the meeting, he gave a presentation on GLOBE backscatter modeling. He also traveled November 17-18, 1993, to Ann Arbor, Michigan, with Dr. George D. Emmitt, of Simpson Weather Associates, to visit with Dr.'s Paul Hays and Wilbert Skinner, of the University of Michigan. The purpose of the visit was to discuss science needs for new wind measurements and operating principles for coherent and incoherent Doppler wind lidars. From January 31-February 3, 1994, he traveled to Clearwater, Florida, to participate in a meeting of NASA's Laser Atmospheric Wind Sounder (LAWS) Science Team. During the meeting, he gave a presentation on GLOBE results.

Dr. Timothy Rushing traveled to Kennedy Space Flight Center, Florida, to install the Wind Profiler system, November 16-19, 1993.

Dr. Mike Newchurch traveled to San Francisco, California, to attend the AGU Fall meeting and present a paper entitled, "Stratospheric Chlorine Partitioning Modeling with SL-3 ATMOS and Balloon Microwave Limb Sounding Measurements." This paper is the result of work that was done in conjunction with the ATLAS program under the science direction of Dr. M. Allen and Dr. R. Stachnik, December 5-11, 1993.

Mr. Dennis Buechler traveled to San Francisco, CA, December 6-10, 1993, to attend the American Geophysical Union Fall Meeting. He presented the paper entitled, "Preliminary Investigation of Using Lightning Data as an Indicator of Convective Precipitation," The paper was published as an abstract in Transactions, American Geophysical Union, San Francisco, CA, p 153. He also presented a brief overview of the OTD (Optical Transient Detector) instrument at the CASE (Committee on Atmospheric and Space Electricity) meeting on December 9, 1993.

Dr. Doug Mach attended an ABFM meeting at KSC over the week of February 14, 1994. He presented some of the latest results of the ABFM analysis that was done over the last few years. As a result of these results, new LCC rules have been proposed and are in the process of being approved by NASA management.

SPECIAL WORKSHOPS/MEETINGS

The University hosted the First Earth Science Division Stategic Planning Meeting at the University on November 23, 1993.

The University has provided support for the following scientific meetings over the past 6 months:

December 14-15, 1993 A preliminary LAWS meeting was held in Huntsville, AL in preparation for the upcoming LAWS Science Team Meeting.

February 1-3, 1994 The LAWS Science Team Meeting was held in Clearwater, Florida.

February 26, 1994 The program visit to MSFC by Dr. Kennel, Associate Director for Mission to Planet Earth.

ACTIVITIES SPONSORED BY USRA

SUBCONTRACTS

Drexel University

USRA entered into a subcontract agreement with Drexel University with Dr. Donald J. Perkey serving as Principal Investigator, to perform research entitled, "Direct Global Change Research Related to the Earth's Energy and Hydrologic Cycle." The subcontract number is 3400-01 with a period of performance of September 1, 1993 through December 31, 1993. The Scope of Work consisted of the following activities:

1) Dr. Perkey assist in developing effective working relationships between the National Aeronautics and Space Administration (NASA) and university scientists to address research needs for the University of Alabama in Huntsville relative to the establishment of a coordinated program of Earth science research;
2) Dr. Perkey study the role of the hydrologic cycle in the dynamics and energetics of atmospheric circulations;
3) Dr. Perkey interact on a regular basis with UAH and USRA scientists regarding progress on their scientific endeavors and with responsible NASA counterparts regarding the status of their cognizant programs.

A Final Report which describes his activities is attached as Appendix 1.

Drexel University

Drexel University reentered into a subcontract, 3400-03, to continue supporting Dr. Perkey's assignment. The tasks are described above and will remain the same through March 31, 1994.

University of Bristol

USRA entered into a subcontract with the University of Bristol, Remote Sensing Unit, subcontract number 3400-02, with Dr. Eric C. Barrett serving as Principal Investigator to perform research entitled, "The WETNET Project: Rainfall Algorithm Intercomparison and Development, Stage V Part Two." The period of performance began September 1, 1993 through January 31, 1994. The Scope of Work consisted of the following activities:

1) To pursue a program of research for the RSU to accomplish the aims and objectives of the WetNet Project as a whole, particularly related to the Rainfall Algorithm Intercomparison and Development and participation in Research Review meetings and related activities in the area focused research for the WETNET Group. Specifically, perform work for the:
   a) Planning and editing a special edition of the refereed journal *Remote Sensing Review* dedicated to the PIP-1 project, its justification, science and results;
   b) Help to plan and participate in, the PIP-2 experiment aimed at selected rainfall case study analyses;

c) Organization and participation in the PIP-1 Follow-on exercise, aimed at the design, development and improved calibration of SSM-I based "community algorithms" for global application.

An outline for worked performed during this Semi-Annual reporting period is attached as Appendix 2.

University of Bristol

Dr. Eric Barrett from the University of Bristol will continue working on Phase VI which will be a continuation of work which is described above. Stage VI will continue through January 31, 1995, under subcontract number 3400-05, to focus on the following research related to remote sensing:

1) Complete the report on the PIP-1 results;
2) Prepare SSM/I-based results for the GPCP AIP-3 Intercomparison Project;
3) Participate in the WetNet PIP-2 Intercomparison Project;
4) Continue research on the definition and development of a "composite algorithm" problem solution approach;
5) Participate in the preparation for PIP-3;
6) Organize the European WetNet Laboratories meeting.

Drexel University

USRA assigned Drexel University as a subcontractor, 3400-04, effective January 5, 1994, for Dr. Carl W. Kreitzberg, Principal Investigator, to direct the research of Ph.D. candidate, Mr. Kevin Doty, in research related to Global Energy and Water Cycle Experiment (GEWEX) by studying the complete hydrological cycle of the Mississippi River Basin. The goal will be to see what the important space and time scales are based on a model data set that will give insight to the needed scales of observation during GEWEX Continental International Project (GCIP). More specifically,

1) The study will involve the testing of a downdraft parameterization that has been developed during the past year for inclusion with the existing cumulus parameterization in the Limited-Area Mesoscale Prediction System (LAMPS);
2) The study will involve a long integration of the LAMPS model on the order of a month over the GCIP domain on a 35-km mesh with time-dependent boundary conditions.

The two main diagnostic quantities to be computed will be the total derivatives of temperature and specific humidity.

CONSULTANTS

Dr. Kevin Driscoll from Auburn, Alabama, was appointed as a consultant from November 15, 1993 through January 31, 1994. He collaborated with Dr. Hugh Christian and Dr. Rich

Blakeslee, NASA scientists, in the Earth Observing Branch/Earth Science and Applications Division. His scope of work included the following tasks:

1) Analyze lighting and related ancillary observations obtained during the TOGA COARE and CaPE field programs in order to investigate relationships between lightning and underlying and interrelated phenomena (e.g., structure, dynamics, and evolution of thunderstorms; precipitation distribution and amounts; atmospheric chemistry; thunderstorm electric generator and global electric circuit; magnetospheric/ionospheric coupling). As part of this activity, develop, test, and refine quantitative relationships and employ lightning data such as would be obtained from satellite-based lightning detectors.

Technical reports are attached as Appendix 3.

Dr. Pui King Chan from State College, Pennsylvania, was retained as a consultant to travel to NASA/MSFC to give a seminar entitled, "The Cloud-Radiative Consistency Method and its Application to the Monsoon Region." The dates of travel were December 12-17, 1993.

Dr. Scott Dembek from Drexel University in Philadelphia, PA, served as a consultant from October 1, 1993 through March 31, 1994, to

1) Develop, maintain, and test the evolving code for the Limited Area Mesoscale Prediction System (LAMPS). This included working with (a) IGCRE scientist Dr. Charles Cohen to test new cloud and ice parameterization in the LAMPS model, (b) NASA scientists Dr. Franklin Robertson and Mr. Kevin Doty to modify the LAMPS code to run across the equator and the international dateline.

2) Develop, maintain, and test codes to diagnose atmospheric moisture and energy budgets as applied to LAMPS and other model simulations. This included working with (a) IGCRE scientist Dr. Donald Perkey and NASA scientist Dr. Franklin Robertson to develop and test cloud-radiation diagnostics.

Dr. Takmeng Wong from Colorado State University in Fort Collins, CO, was retained as a consultant to visit NASA/MSFC to give a presentation entitled, "On the Radiative Processes Associated with the Tropical Mesoscale Convective Systems," December 11-13, 1993.

Dr. John Latham from Manchester, England, was appointed to work with Dr. Hugh Christian through December 31, 1993, on research directed toward assessing the value of the lightning mapper sensor. His effort included the following tasks:

1) Develop energy budget/prediction algorithms to correlate cloud dynamics and precipitation with lightning and electric field measurements;

2) Analyze radar, aircraft-based cloud microphysical and electric field data from the CaPE and TOGA-COARE experiments. Compare and correlate analyses with predictions of the formation of precipitation and the generation/distribution of electric fields in clouds from current understanding and the results of explicit cloud physics models.

3) Interpret LIS observations and analyses in terms of accepted cloud microphysical and electrification theories.

4) Based on the interpretation of the existing LIS database, to develop as feasible specific concepts with regard to the categorization of the electrical properties of tropical clouds on the basis of cloud type and stage of cloud development.

A final report is attached as Appendix 4.

Dr. Byung-Ju Sohn from Seoul National University in Seoul, Korea, was retained as a consultant, from December 26, 1993 through March 1, 1994, to accomplish the following tasks:

1) Perform studies of the use of numerical models and space based data leading to better understanding and prediction of the behavior of the earth atmosphere system;

2) Conduct diagnostic and numerical studies of cloud radiative effects on atmospheric energetics, ISCCP cloud data, ERB TOA fluxes, ECMWF analyses and MSU and SSM/I temperature and moisture data used to diagnose vertical profiles of radiative heating. The specific tasks for this effort are as follow:

   a) Perform quality checks on derived radiative heating profiles;
   b) Test diagnostic codes for APE generation and conversion, and forcing of 3-D divergent circulations;
   c) Complete calculations of thermally forced 3-D divergent circulations, including partitioning of clear and cloudy induced components;
   d) Outline paper of results for journal submission.

Dr. Sohn attended the AMS meeting in Nashville, TN, January 27-28, 1994, and presented two papers, one entitled, "Is Cloudiness Information Really Necessary in Estimating Net Solar Radiation at the Surface from Satellite Measurements?" and one entitled, "Comparison of Radiation Calculations Using Diagnosed Versus Prognosed Cloud and Rainwater Amounts."

TRAVEL

Dr. Charles Cohen attended the 17th Conference on Severe Local Storms in St. Louis on Oct. 4-8, and presented, in a poster session, the results of a comparison of two cumulus parameterizations in mesoscale simulations of cloud lines. The results were entitled, "A Comparison of Two Cumulus Parameterizations in Mesoscale Numerical Simulations of Moving Cloud Lines."

Dr. Shouping Wang traveled to Nashville, TN, to attend the 8th Conference on Atmospheric Climate Variations organized by the American Meteorological Society, January 26-27, 1994.

Dr. Donald Perkey traveled to Nashville, TN, to participate in the 6th Conference on Climate Variations organized by the American Meteorological Society, January 27, 1994. He gave a presentation.

Dr. Huei-Iin Lu attended the 1st Pacific International Conference on Aerospace Science and Technology from December 6-9, 1993, in Tainan, Taiwan to present a paper entitled, "Numerical Simulations for Geophysical Fluid Flow Experiments." He also attended the 6th Conference on Climate Variations Jan. 25, 1994, in Nashville, TN to present a paper entitled, "Intransitivities in Numerical Climate Prediction."

SPECIAL PROJECTS:

PROGRAM - University-Based Cooperative Program in Earth Systems Science Education (ESSE)

ELIGIBLE PARTICIPANTS - The program is targeted for universities throughout the United States with a commitment to developing an interdisciplinary Earth science program at their institution. The audience served by the project is undergraduate students. Since this program has proven to be successful, it has been expanded to include other universities and graduate-level students, as well as arrangements for postdoctoral research opportunities at NASA and universities.

PROGRAM DESCRIPTION - Under this pilot program, selected universities are participating cooperatively with other universities and NASA in two inter-related activities--curriculum development and scientific exchange. Each university is required to develop and offer an introductory survey course in Earth systems science and senior-level, interdisciplinary course. The introductory course presents an overview of Earth systems science to a broad segment of the student body, including both science and non-science majors. The purpose of the senior level course is to attract those undergraduate science majors with solid foundations in relevant sciences to future studies and work in Earth systems science. The senior level course is taught jointly by faculty members from at least two academic departments with supplemental lectures from other in-house faculty, advanced graduate students, postdoctoral students, as well as visiting faculty and researchers from other universities or NASA laboratories. In addition, to the curriculum development portion of the program, each university participates in an effort involving short-term visiting scientists from other participating universities and NASA Field Centers. These visitors provide additional technical insight and foster interdisciplinary education and research through their special expertise from a NASA Center who serves as a sponsor for their academic program. The NASA-sponsoring scientist may join in the identification and formulation of course work and relevant projects, facilitate access to NASA data, technical material, and other resources, and locate other NASA-based scientists to serve in a resource lecture pool from which universities may draw visiting lecturers.

Each participating university and the principal investigator are required to report on courses taught during the year and provide travel records for the visiting faculty.

ESSE TRAVEL

Faculty Exchange Travel:

Dr. Gary Ernst from Stanford University traveled to the University of Minnesota, November 10-12, 1993, to discuss the development of Earth System Science courses and other ESSE related issues at Minnesota with Dr. Kerry Kelts. Dr. Ernst gave two presentations, one entitled, "Petrotectonic Evolution of Klamath Arc," and one entitled, "Earth Systems Science Curricula: How We Did It at Stanford."

Dr. Roger Bales from the University of Arizona traveled to Utah State University, February 7-8, 1994, to provide special expertise and perspectives to benefit their curriculum development.

Dr. Michael Arthur from Pennsylvania State University traveled to the University of Florida, February 9-12, 1994, to participate in the travel-exchange of faculty between the participating schools to become a resource for the development of interdisciplinary earth science courses.

Dr. Fred Mackenzie from the University of Hawaii traveled to Northwestern University to visit with Dr. Abraham Lerman, February 18-24, 1994. He gave a lecture to the ESS undergraduate classes and presented a seminar.

Dr. Richard Minnich from the University of California in Riverside, CA, traveled to Utah State University to meet and hold discussions with Dr. Robert Ford, February 21-24, 1994.

Other Travel/Visits:

Dr. Donald R. Johnson traveled to San Francisco, CA, to present a paper on NASA/USRA Earth System Science Education at the American Geophysical Union Meeting, Fall meeting held December 2-13, 1993. A preprint of his paper presented is attached as Appendix 5.

APPENDIX 1

Direct Global Change Research Related to the Earth's Energy and Hydrologic Cycle

USRA Subcontract 3400-01

Final Report to
Universities Space Research Association
4950 Corporate Drive
Suite 100
Huntsville, AL 35806

from

Department of Physics and Atmospheric Science
Drexel University
Philadelphia, PA 19104

Reporting Period: 1 September 1993 - 31 December 1993

Principal Investigator: Donald J. Perkey Date: 3/1/94
Donald J. Perkey
Department of Physics and Atmospheric Science

Summary

This is a final report from Drexel University for a subcontract to Universities Space Research Association (USRA) in Huntsville, AL for the services of Dr. Donald Perkey.

During the four-month period of this subcontract, Dr. Perkey proposed to function as the Interim Director of the Institute for Global Change Research and Education (IGCRE). IGCRE is jointly operated by the Universities Space Research Association and University of Alabama in Huntsville. The duties of the Interim Director include:

- develop effective working relationships among NASA, UAH and USRA scientists to address the research and educational programs of IGCRE.
- oversee the management, operations and activities of IGCRE.
- study the role of the hydrologic cycle in the dynamics and energetics of atmospheric circulations.

Dr. Perkey has continued to work with National Aeronautics and Space Administration (NASA), University of Alabama in Huntsville (UAH) and USRA scientists to develop methods of interaction for research in global change science relative to the Mission to Planet Earth and to advance the understanding of the role of water and energy in the dynamics of global change. He has provided management and operations oversight for IGCRE and has worked with IGCRE management staff to develop financial management reports for use by IGCRE management. During this time he has also held an Executive Board (12/1/93) meeting to report on the status of IGCRE.

In addition, Dr. Perkey has continued to collaborate with NASA and Drexel scientists studying the impact of spatial and temporal sampling resolution on model diagnostic heat and moisture budgets. He has compared the diagnosed longwave radiation profiles and budgets that result from a general circulation model with those diagnosed from a regional-scale numerical model. Results will be presented at the AMS 6th Conference on Climate Variations to be held in Nashville in January 1994.

1. INTRODUCTION

This is the final report from Drexel University for a subcontract to Universities Space Research Association (USRA) in Huntsville, AL for the services of Dr. Donald Perkey. USRA requested that during the four-month period of this subcontract, Dr. Perkey function as the Interim Director of the Institute for Global Change Research and Education (IGCRE). IGCRE is jointly operated by the Universities Space Research Association and University of Alabama in Huntsville. The duties of the Interim Director include:

- develop effective working relationships among NASA, UAH and USRA scientists to address the research and educational programs of IGCRE.
- oversee the management, operations and activities of IGCRE.
- study the role of the hydrologic cycle in the dynamics and energetics of atmospheric circulations.

2. PROPOSED TASKS AND RESULTS

Specific tasks as stated in the proposal for this four-month period and the results of each task are stated below. Dr. Perkey

Task 1 will develop effective working relationships among NASA, UAH and USRA scientists to address the research and educational programs of IGCRE.

Results has continued to work with NASA, UAH and USRA scientists to develop methods of interaction for research in global change science. This includes hosting and participating in the NASA strategic planning meeting held 23 November 1993.

Task 2 will oversee the management, operations and activities of IGCRE.

Results has provided management and operations oversight for IGCRE. He has worked with IGCRE staff to develop financial management reports for use by IGCRE management. In addition, he held an Executive Board (12/1/93) meeting to report on the status of IGCRE.

Task 3 will study the role of the hydrologic cycle in the dynamics and energetics of atmospheric circulations.

Results has continued to collaborate with NASA and Drexel scientists studying the impact of spatial and temporal sampling resolution on model diagnostic heat and moisture budgets.

In addition Dr. Perkey has compared the diagnosed longwave radiation profiles and budgets that result from a general circulation model with those diagnosed from a regional-scale numerical model. Results will be presented at the AMS 6th Conference on Climate Variations to be held in Nashville in January 1994.

3. PUBLICATIONS AND PRESENTATIONS

Perkey, D.J., S.R. Dembek, F.R. Robertson, and B.-J. Sohn, 1994: Comparison of radiation calculations using diagnosed versus prognosed cloud and rain water amounts. Preprints of the AMS 6th Conf. on Climate Variations. Nashville, 23-28 Jan., 318-322.

4. TRAVEL IN SUPPORT OF ASSOCIATED SCIENCE

10/18/93-10/19/93 participated the NOAA Office of Global Program's GCIP/GIST Design Meeting in Norman, OK.

10/20/93-10/21/93 participated the NOAA Office of Global Program's GEWEX/GCIP Science Panel Meeting in Norman, OK.

11/8/93-11/12/93 attended the Regional Photochemical Measurement & Modeling Studies Conference in San Diego, CA.

12/14/93-12/16/93 participated in the Ph.D. thesis defense of Robert Cohen at Drexel University in Philadelphia, PA.

5. EQUIPMENT PURCHASES

No equipment has been purchased by this subcontract. However, equipment purchased by the previous USRA subcontract resides with Dr. Perkey and has continued to be used on this USRA subcontract.

APPENDIX 2

Section I SUMMARY OF STAGE V ACTIVITIES

Work during 1993 has consisted of the following principal activities:

(1) Continuation and completion of the analysis of results from PIP-1 (nearly 20 SSM/I algorithms from more than a dozen laboratories), and their intercomparison, in close liaison with MSFC (especially M. Goodman and B. Motta).

(2) Organisation of the PIP-1 Results Workshop in Bristol, UK, from 10-12 May 1993.

(3) Planning and editing a special edition of the refereed journal *Remote Sensing Review* dedicated to the PIP-1 project, its justification, science and results.

(4) Helping to plan, and participate in, the PIP-2 experiment aimed at selected rainfall case study analyses.

(5) Initial definition of a PIP-1 Follow-on exercise ("PIP-3"), aimed at the design, development and improved calibration of SSM/I-based "community algorithms" for global application.

(6) Consideration of ways in which near real-time SSM/I browse products might be put to practical use.

(7) Liaison with other international groups and projects (e.g. GPCP, the EEC "Storm" Project, NOAA-Nile, HYREX etc.) for cross-fertilisation of ideas and methods.

(8) Liaison with other WetNet WGs to identify, plan and if possible implement, inter-WG activities, e.g. aimed at studies of "cross-talk" between products prepared from different parameter-specific algorithms.

(9) Continued leadership of the Precip WG through ECB as Chair.

(10) Preparation of journal and conference papers reporting WetNet research activities and findings.

The major document describing these activities is the *PIP-1 Results Volume* to be published as a special edition of *Remote Sensing Reviews* in April or May 1994, edited by E.C. Barrett. Contents of this volume are set out in Table 1.

APPENDIX 3

MEMORANDUM

To: Donald Perkey, IGCRE Interim Director
cc: Maurice Estes, Jr.

From: Kevin Driscoll, Consultant to IGCRE

Date: December 31, 1993

Subject: Progress during December consulting period

From December 1 through December 31, 1993, I continued to work with members of the Earth System Observing Branch/Earth Science and Applications Division by analyzing the electrical measurements obtained during the TOGA COARE and CaPE field programs. The data being examined includes electrical measurements produced by two electric field mills and two conductivity probes mounted aboard a NASA ER-2 aircraft which flew above electrified thunderstorms.

In an effort to investigate the electrical characteristics of the thunderstorms observed during these field programs, it has been necessary to compare the measured electric fields with the results of a computer generated simulation. During this investigation it was discovered that the data provided by the electric field mills were indeed influenced by the electrical enhancement of the ER-2 aircraft. In addition, it was discovered that the measured electric fields obtained above electrified clouds were generally higher than expected. To ensure that these measurements were not a result of a calibration error, it was determined that the calibration procedure and the resulting calibration parameters need to be re-examined for both the conductivity probes and the electric field mills.

From the records of the calibration procedure for the conductivity probes, it was determined that there was more than a 10% uncertainty in the capacitance of the probes and less than a 2% uncertainty in the gain of the amplifier stage. In addition, microphonic noise affected the output voltages of both the probes. The calibration records showed that the capacitance of probe #1 was approximately 3.9pF and the amplifier stage was recalculated and found to have a gain of approximately 900 GVolts/Ampere. Since the conduction currents present in the atmosphere are calculated from a multiplication of the conductivity and the electric fields, the error in the computed conduction currents obtained from the conductivity probes and the field mills will have an uncertainty between 10% and 15%.

Through an examination of the calibration procedure for the electric field mills, it was estimated that the error associated with the computation of the conversion factor is less an 10%. These conversion factors were extracted from the calibration data, and these parameters were found to be 30kV/volt for field mill #1, 74kV/volt for field mill #2, and 24kV/volt for field mill #3 when examining the output of the low gain amplifier stage.

The medium gain and high gain stages for these field mills have conversion factors which ware approximately a factor of 44 and 1950 times less than the above numbers.

During the month of December, there has been much effort directed toward the retrieval and examination of the data measured during the TOGA COARE field program. However, to ensure that a proper analysis could be performed, the calibration procedures were re-examined and the conversion factors were calculated for both the field mills and the conductivity probes used during the field programs. The information gained from this month's efforts can now be used to determine the accuracy of the electrical measurements over electrified thunderstorm. As a result, a better understanding of the data will be achieved during its examination throughout the following months.

MEMORANDUM

To: Donald Perkey, IGCRE Interim Director
cc: Maurice Estes, Jr.

From: Kevin Driscoll, Consultant to IGCRE

Date: January 31, 1993

Subject: Progress during January consulting period

Throughout the month of January, I have continued to work with members of the Earth System Observing Branch/Earth Science and Applications Division in an effort to analyze electric field measurements obtained during the TOGA COARE and CaPE field programs. Although the analysis of the electrical measurements obtained during these field programs has provided some insight into the electrical structure of several storms, a large percentage of the efforts for this month was directed towards the continuation of the calibration process for the electric field mills and the conductivity probe that were mounted aboard the ER-2 aircraft.

While attempting to complete the calibration of the conductivity probes, it was discovered that the conductivity of the atmosphere derived from the measurements obtained during TOGA COARE were less than what would be expected. As stated in the previous month's report, the capacitance of one of the probes had been measured 3.9 pF, and the gain of the amplifier stage had been determined to be 900 GVolts/Ampere. By combining these values with the digitized conductivity data recorded during the field program, the newly computed conductivity of the atmosphere was found to be about four times less than the measurements previously published by other scientists in other parts of the world. This discrepancy has not been explained, although there are several possible reasons for this error. Some possibilities for this error include simple software problem in the data acquisition software, the non-linear performance of the op-amp in the amplifier stage for low input currents, or the improper measurement of the probe capacitance. All of these possibilities for error have been discussed with the engineering staff responsible for this instrument, but no definitive explanation for the error has be identified. In the coming month, as time permits, the most likely causes for the conductivity measurement error will be investigated further.

The calibration process for the electric field mills mounted on the ER-2 aircraft has also continued throughout this month. A satisfactory set of relative calibration parameters has been obtained for these field mills that has been used to determine the relative horizontal and vertical electric fields produced by electrified storm cells. The absolute calibration of these field mills will be performed during the coming weeks through the comparison of measurements obtained by the fully calibrated measurements obtained by the DC-8 aircraft which in the same general vicinity as the ER-2 aircraft on several days of the TOGA COARE field program.

While working toward the relative calibration of the electric field mills, an investigation was initiated in order to characterize the relationships that exist between the vertical and horizontal electric fields present over bipolar thunderstorms. The purpose of this investigation was to gain insight into the relative ratios of vertical and horizontal electric fields for regions above electrified storm cells. Through a comparison of measured and simulated electric fields, it was discovered that some of the storm cells observed during TOGA COARE possessed charge structures that were displaced both vertically and horizontally, thus explaining the asymmetric behavior in the horizontal electric fields recorded by the ER-2 aircraft as it flew directly over several storm cells. Through further examination of the relationships between the vertical and horizontal electric fields, it can be expected that the relative location of the ER-2

aircraft to the center of the electrified storm cells can be obtained using only two electric field mills mounted on the aircraft.

In the coming weeks, the instantaneous electric field changes associated with lightning will be examined in order to obtain an absolute calibration of the field mill data and to examine the electrical characteristics of active thunderstorms observed during the TOGA COARE and CaPE field experiments. In addition, other data obtained during this field program, such as radar and LLP information, will also be examined in an effort to characterize the electrical properties of active thunderstorms.

APPENDIX 4

DEVELOPMENT OF A MODEL FOR THE PRODUCTION OF ALGORITHMS IN CONNECTION WITH DATA FROM THE NASA/MSFC LIGHTNING IMAGING SENSOR (LIS)

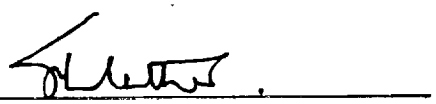
Report of IGCRE (Attn: Mr. Maury Estes)

Contract SUB93-216

by

Dr. John Latham
26 Lapwing Lane
Didsbury
Manchester M6O 1QD
England

December 1993



John Latham

THE MODEL

The model exists in a variety of closely related forms, a representative version of which is illustrated in Figure 1. In the immediately following paragraphs it will be described qualitatively; after which the salient non-standard equations will be presented.

An updraught of specified constant speed U and width W is moving continuously through an environment whose meteorological sounding is prescribed and remains fixed throughout the period covered by each cloud simulation experiment. This ascent creates a cylindrical cloud of width W, with its axis vertical, whose base is at a pressure, altitude and temperature pb, zb and tb (>0C) respectively.

Above zb the cloud contains droplets (corresponding to a liquid-water-content L, released by condensation), and (once the cloudy air has risen above the 0C isotherm) ice crystals of number concentration nx and size dx. These solid and liquid particles ascend with speed U. The variation of L with altitude z is prescribed, its sub-adiabaticity representing depletion resulting from entrainment and vapour transfer to the ice phase. The growth of the ice crystals in the ascending air is calculated from the classical diffusion equation, with a form factor F designed to represent the asphericity of the crystals.

The ice crystals originate in two ways, which can be considered to operate in isolation or conjunction:-

A. Primary Nucleation. Following the original work of Fletcher (....). ice crystals are assumed to be formed on nuclei existing

within the cloud (either in the air or in or on supercooled droplets), their number concentration nx increasing exponentially as the temperature falls. Thus at any level above the 0C isotherm there will exist ice crystals of a range of sizes, the smallest and most numerous having just been nucleated.

B. Secondary Nucleation. This process is based on the laboratory experiments of Hallett and Mossop (....), in which it was discovered that within a restricted temperature band (-3 to -8C) the freezing of supercooled water droplets accreted onto the surfaces of growing graupel or hail particles may be accompanied by the ejection of ice splinters. In our model, hailstones (discussed later) falling through this temperature band sweep out supercooled water and thereby generate ice crystals (at a rate derived from the laboratory experiments) which grow as they are swept upwards through the cloud. In this simplest possible description of the Hallett-Mossop process the ice crystal concentration nx (in the absence of primary nucleation) is zero below the -3C isotherm, increases as the temperature falls to -8C, and remains constant at the -8C value at all lower temperatures. Provision exists within the model for taking account of further processes (including the possible role of supercooled raindrops in producing additional ice splinters and expediting rimer formation as they freeze) which enhance the rate of production of ice crystals. In treating this refinement to the basic Hallett-Mossop process use is made of the analytic treatment of Chisnell and Latham (....), which showed that this further enhancement of nx can be represented by a simple exponential relationship.

At some level pi, zi, Ti the cloud is inocculated at a

specified rate F per unit area with embryonic spherical hailstones of diameter Do and constant density rho. These grow according to the classical coalescence equation by the accretion of supercooled water which freezes onto their surfaces. The hailstones have a size-dependent terminal fall-speed V and thus rise (relative to the ground) at a speed U-V until they reach the balance level (pbal, zbal, Tbal), where U-V=0; at which point they begin to descend through cloud towards earth with a continually increasing velocity V-U. Hailstone growth is assumed to cease when the hydrometeors fall through the 0C isotherm. Thus the hailstone are continually growing throughout their period in the supercooled regions of the cloud, and are monodisperse in size at all levels (except that between the levels zi and zbal there are two sizes, one for the upward-moving particles, and one for the descending ones). Throughout their journey below the 0C isotherm, first of all through cloud and then through clear air to ground the hailstone-size is assumed to be constant.

Thus ice crystals, hailstones and supercooled water coexist within the thundercloud at all levels between zbal and the isotherms located at either 0C or -3C (according to which of the above-mentioned glaciation mechanisms is operating). This combination of hydrometeor types is required for the effective operation of the non-inductive ice-ice collisional process of charge transfer (several references), which is generally regarded (further references) as the mechanism most likely to be of primary importance in thunderstorm electrification. Under this mechanism, which is the only charging process considered in the present computations, the charge q separated when a rebounding

collision occurs between a hailstone and an ice crystal depends sensitively on the crystal size dx and the relative fall-speed V of the hydrometeors. The quantitative relationship between q, dx and V is abstracted from the laboratory experiments of Saunders and colleagues (references); and we adopt, from these studies, the finding that at temperatures colder than a reversal value Trev the hailstone is charged negatively by rebounding collisions with crystals, and at temperatures warmer than Trev the hailstones become positively charged. We do not take account in the present work of reports that Trev is dependent upon L.

Thus charge transfer occurs throughout the region of the thundercloud (the interaction zone) in which ice crystals, supercooled water droplets and hailstones coexist; and nowhere else. The parameters pbal, zbal and Tbal define the pressure, altitude and temperature respectively of the upper bound of the interaction zone; and this level - and thus the volume within which charging occurs - increases with increasing updraught speed U.

As gravitational separation of ice crystals and hailstones proceeds, with both types of particles present in the interaction zone, crystals (no hailstones) moving above the balance level into the cloud anvil, and hailstones (no crystals) falling through the base of the interaction zone, through cloud-base and ultimately to ground (where they are assumed to be neutralised), an electric field is developed, the axial component of which (Ez) is calculated over the entire vertical depth of the domain covered by the calculations i.e. from the ground up to cloud-top, whose altitude, temperature and pressure values (ztop, Ttop and ptop respectively) are determined from the meteorological sound-

ing.

In most (though not all) situations the ice-crystals are predominantly positively charged, with a corresponding negative charge on the hailstones. Once air containing charged ice crystals has risen to cloud-top, subsequent charge flowing upwards through the balance level is assumed to be uniformly mixed throughout the depth of the anvil.

Under conditions of adequate charging rate the axial electric field Ez at all levels increases until, at some altitude zzap (where the corresponding pressure and temperature are pzap and Tzap) it reaches a value Ecrit at which lightning is presumed to be initiated. Ecrit is generally taken to be 300kV/M (references), and characteristically it is achieved within the interaction zone, near to its top.

Lightning originating at the level zzap may take the form of either an intra-cloud (I-C) or a cloud-to ground (C_G) stroke.

In the case of an I-C stroke we assume that a fraction E (usually 0.1) of the (generally positive) charge in the cloud anvil is abstracted uniformly from all levels and deposited uniformly in a cylindrical region of cloud of width W and depth zav (of typical value 0.5km) whose upper bound is the balance level zbal. Prior to the lightning stroke this region contains both negative and positive charge, with generally a preponderance of the former. The charge transferred (Q) is assumed to be located on the small cloud particles (ice crystals or droplets) and therefore it immediately starts to move upwards at the updraught speed U. We neglect the possibility that some of it may be deposited on or captured by hailstones. We also neglect neutralisa-

tion of positive and negative charges at the same level.

In the case of a C-G lightning stroke we assume that a charge Q (generally positive) is transferred from the ground to the above-mentioned cylindrical region of depth zav, whereupon it manifests the same behaviour and is subjected to the same restrictions as the positive charge destroyed in an I-C stroke. The magnitude Q of the charge transferred in a C-G stroke is defined by the same criterion as for I-C strokes.

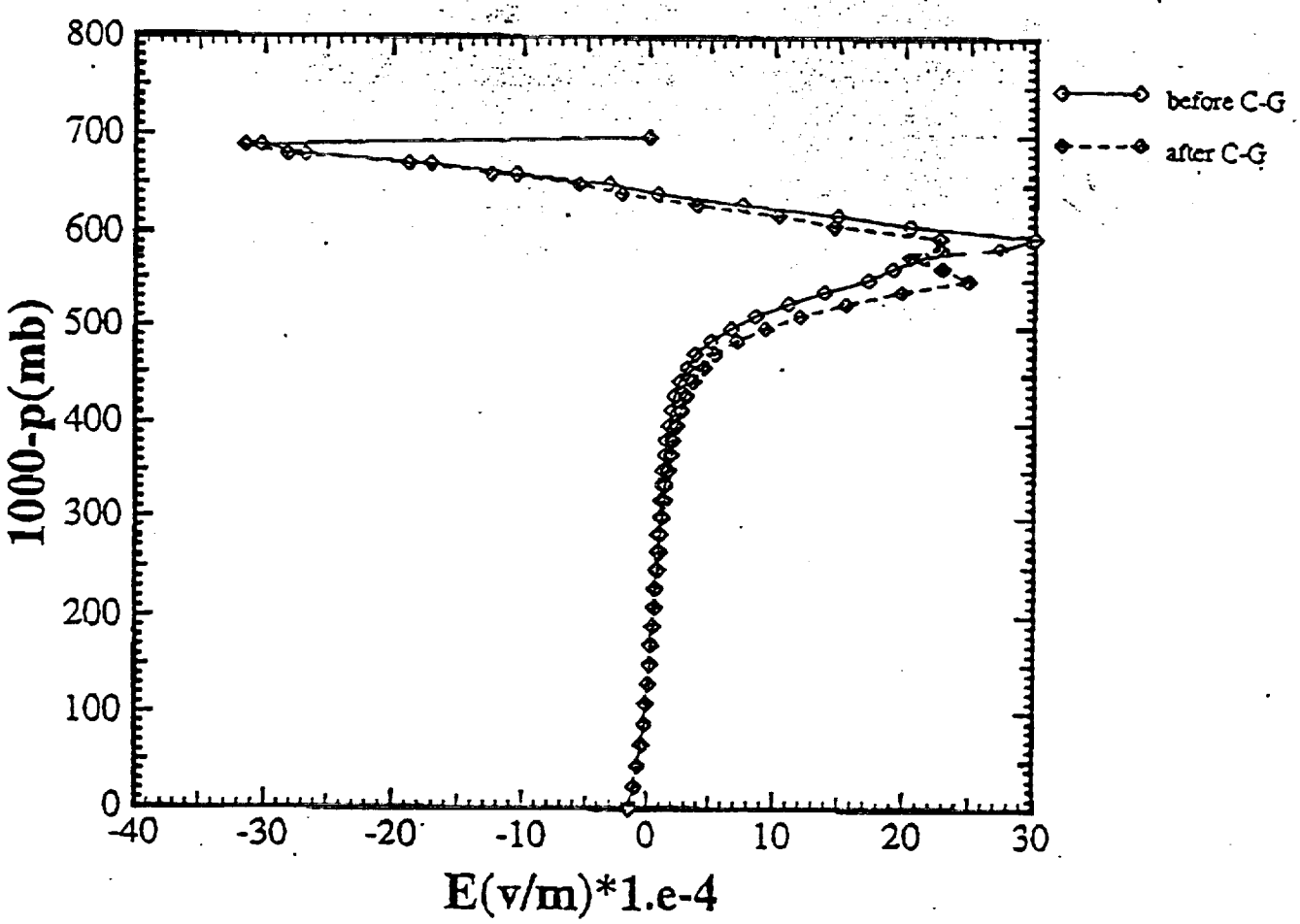
To determine whether a lightning stroke occurring whenever the breakdown field Ecrit is achieved is of the I-C or C-G category, we examine the gradient of the vertical electric field Ez immediately above and below the breakdpwn level zzap at the point when Ez=Ecrit. If the gradient is smaller in the upward direction we assume that the lightning stroke is of the I-C form; whereas a C-G stroke occurs if the gradient is stronger in the downward direction. The rationale for adopting this criterion is that the corona streamers leading to lightning will grow preferentially in stronger ambient fields - from which they can derive more energy in order to facilitate their propagation.

After the lightning stroke has occurred the maximum electric field in the thundercloud is diminished, but as charging via the non-inductive process continues Ez will increase until the value Ecrit is again achieved, and a second lightning stroke occurs. This pattern is reproduced throughout the period of the computations.

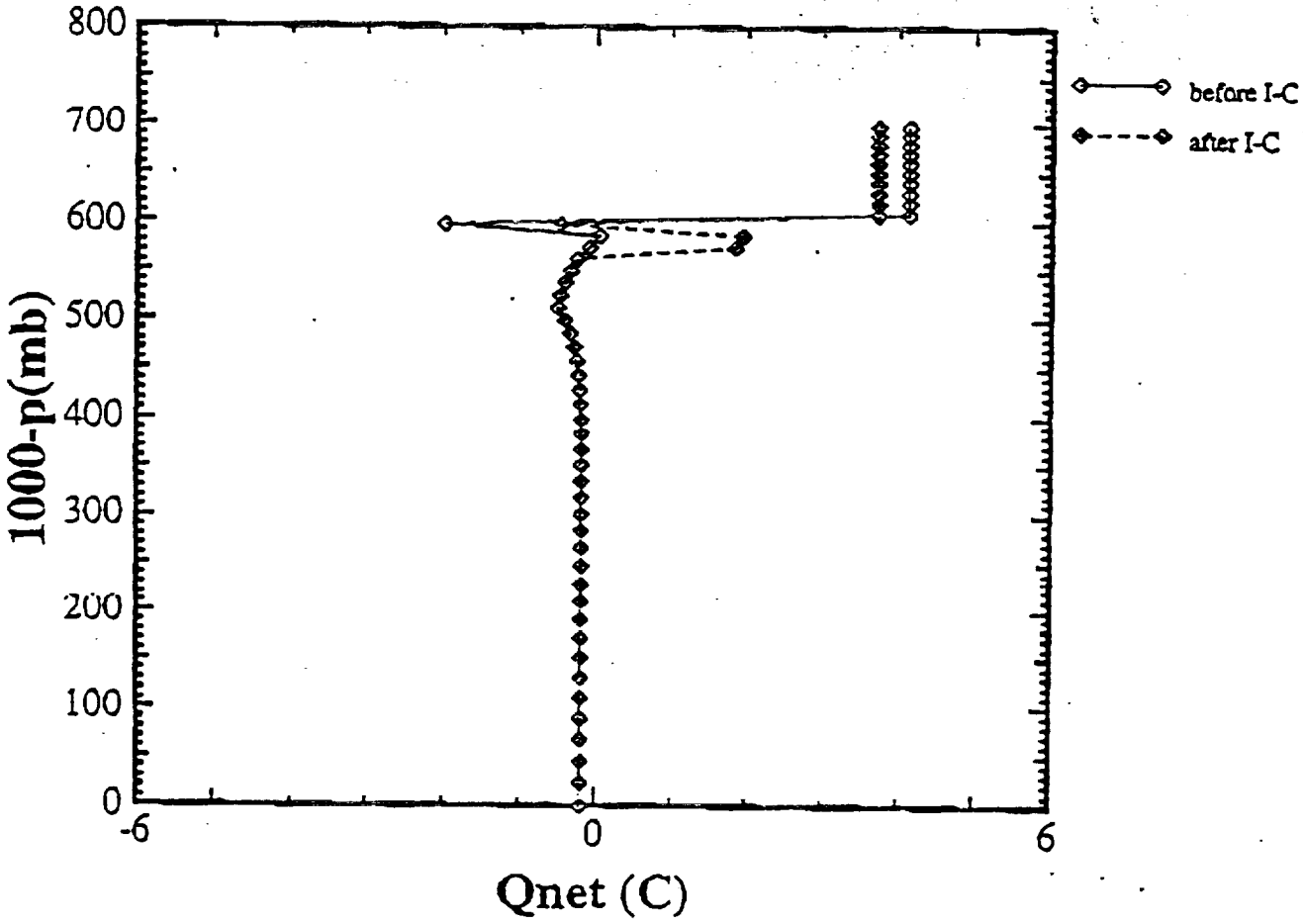
In this way, calculations are made of: times of occurrence of lightning strokes (t1, t2, t3, etc); charge transferred in each one (Q); the altitudinal variation, throughout the computa-

tional period, of axial electric field (Ez), positive charge density (Q+), negative charge density (Q-), precipitation current (Ip), radar reflectivity (Z), precipitation rate (p), hailstone size (D), the number concentration (Nx) and sizes (dx) of ice crystals; and the location (pbal, zbal, Tbal) of the balance level. The above-mentioned parameters are calculated for a specified sounding, altitudinal variation of liquid-water-content (L) and glaciation mechanism; and prescribed values of updraught speed U, cloud width W, hailstone flux F and other parameters defined earlier.

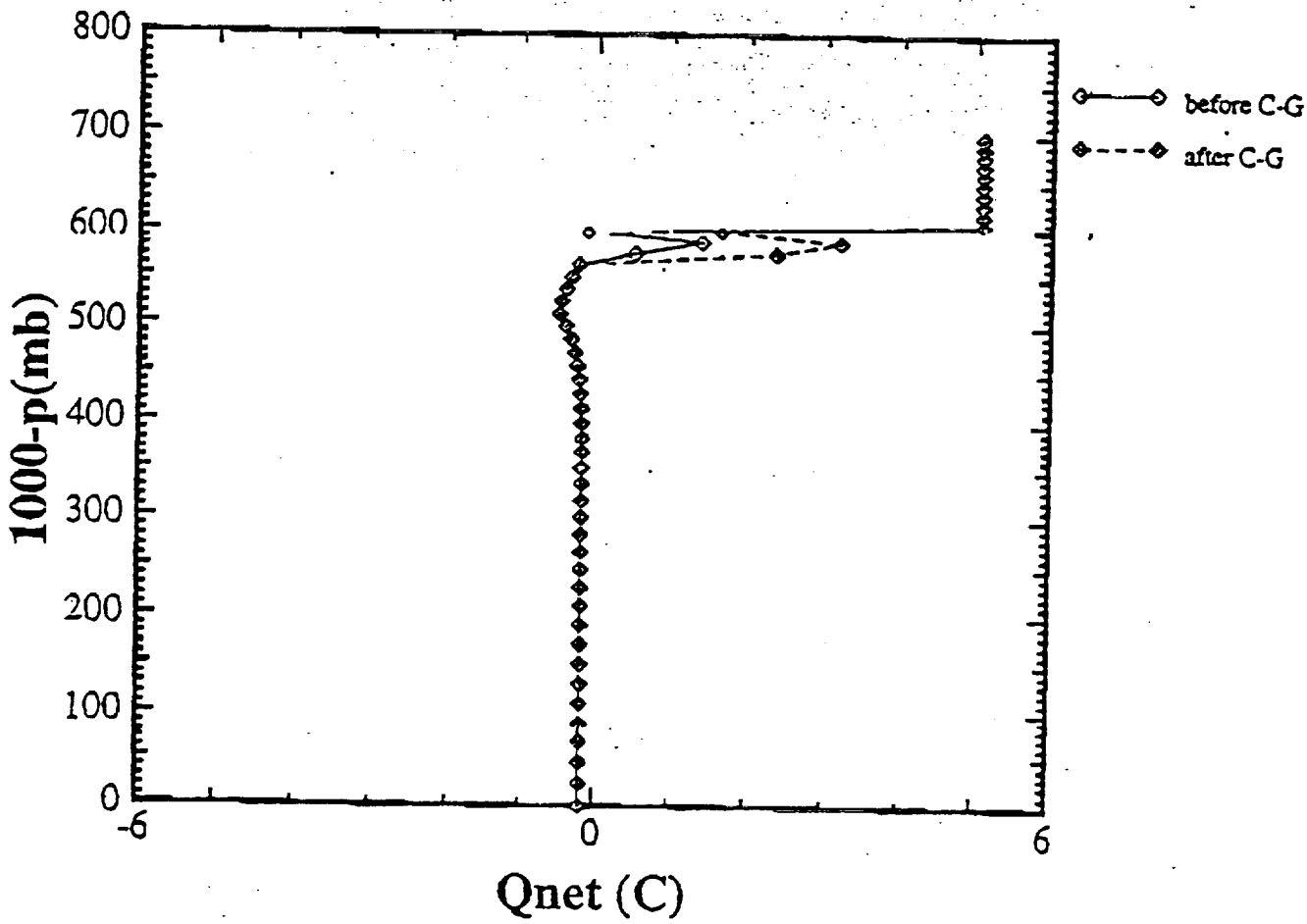
Field Change: C-G Stroke

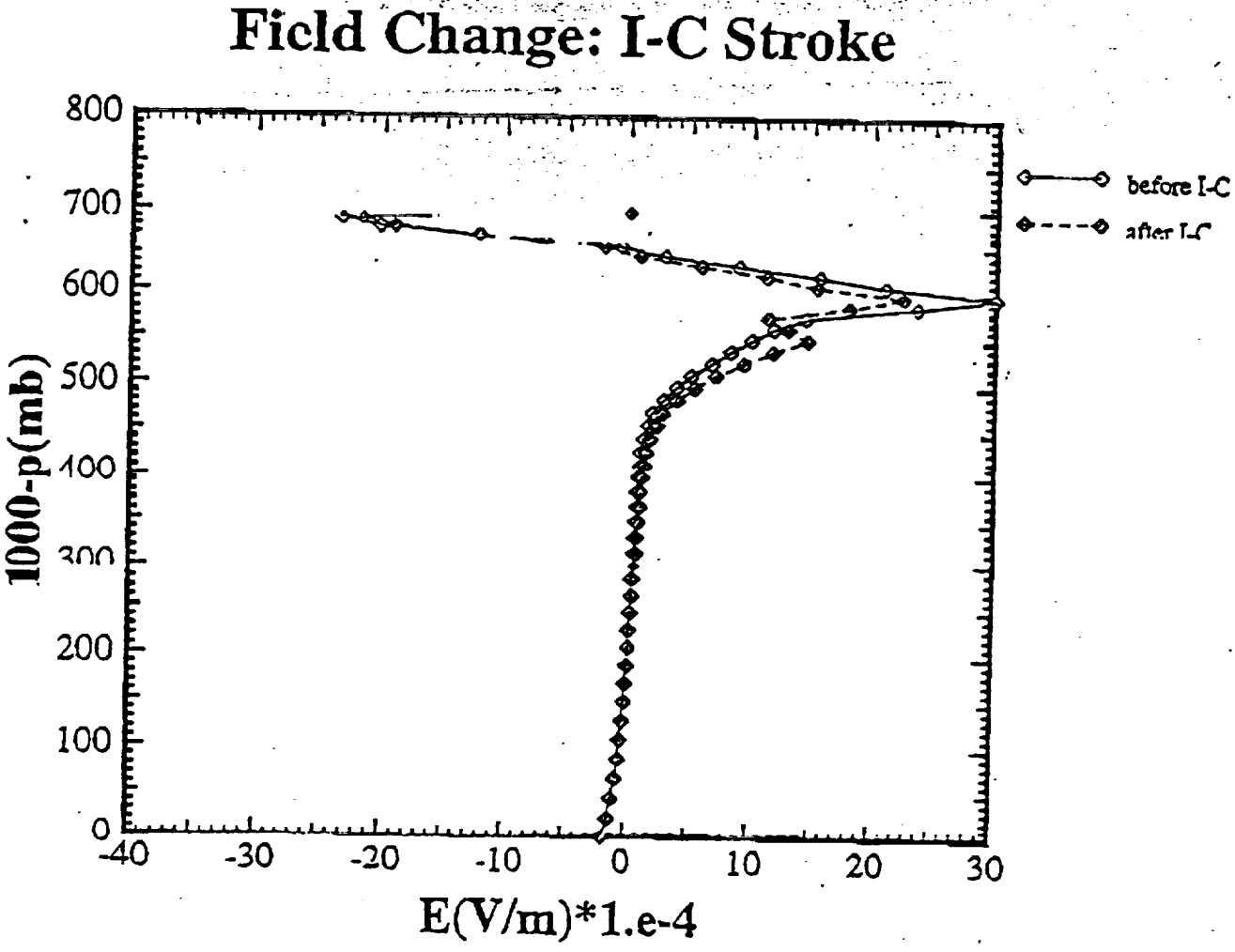


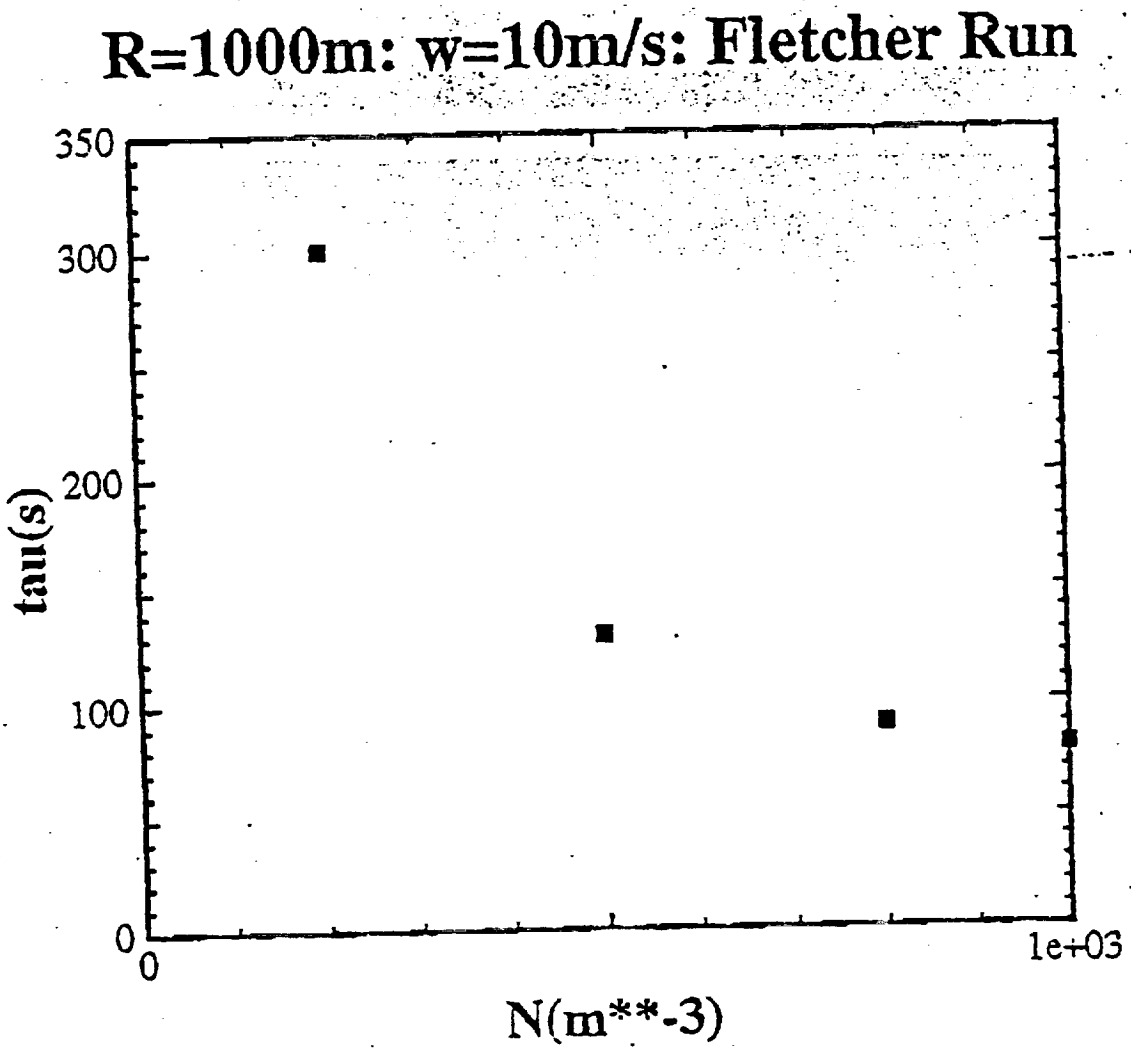
Charge Distribution Change: I-C Stroke



Charge Distribution Change: C-G Stroke




Ficld Change: I-C Stroke
800
700
600
500
400
300
200
100
0
1000-p(mb)
-40
-30
-20
-10
0
10
20
30
E(V/m)*1.e-4
before I-C
after I-C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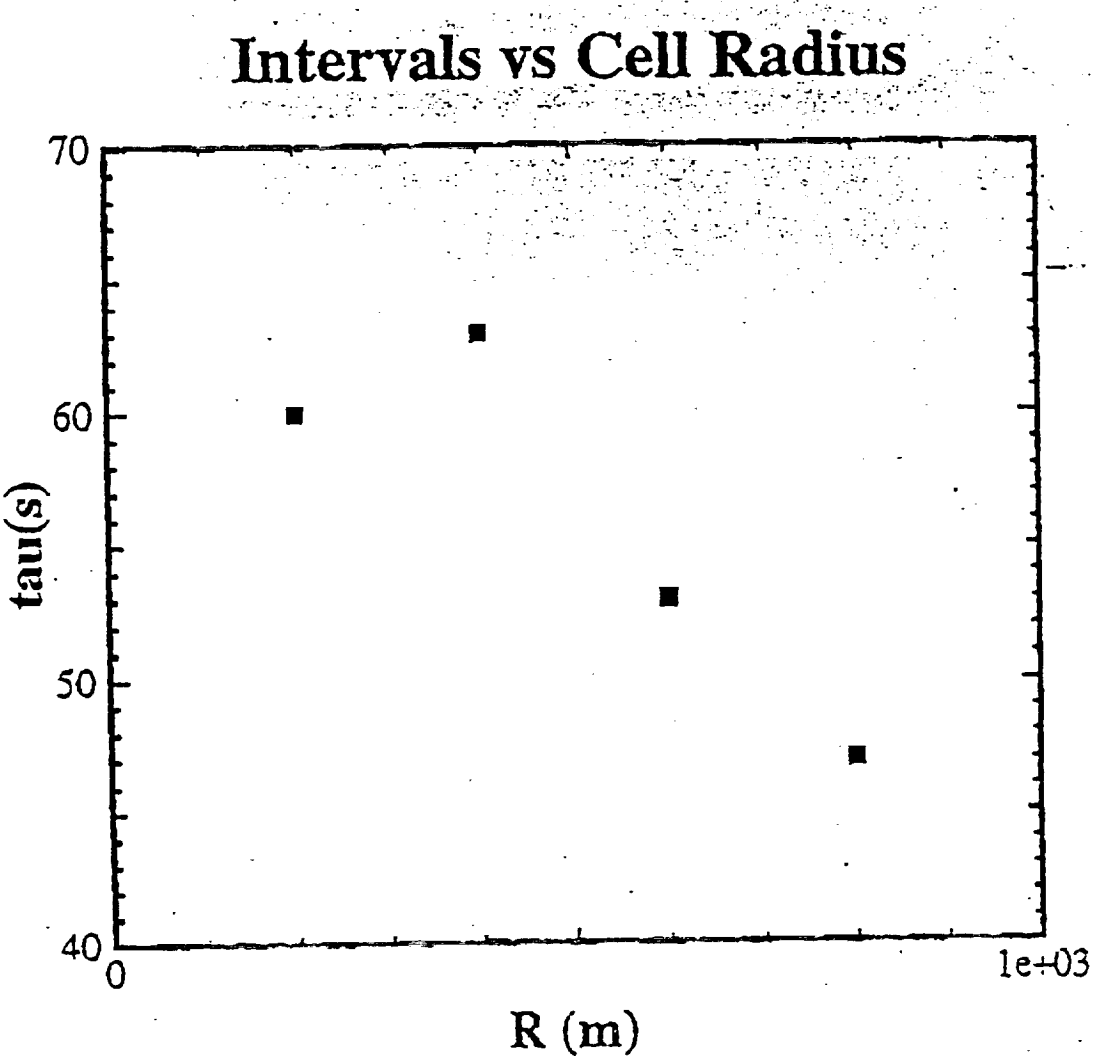
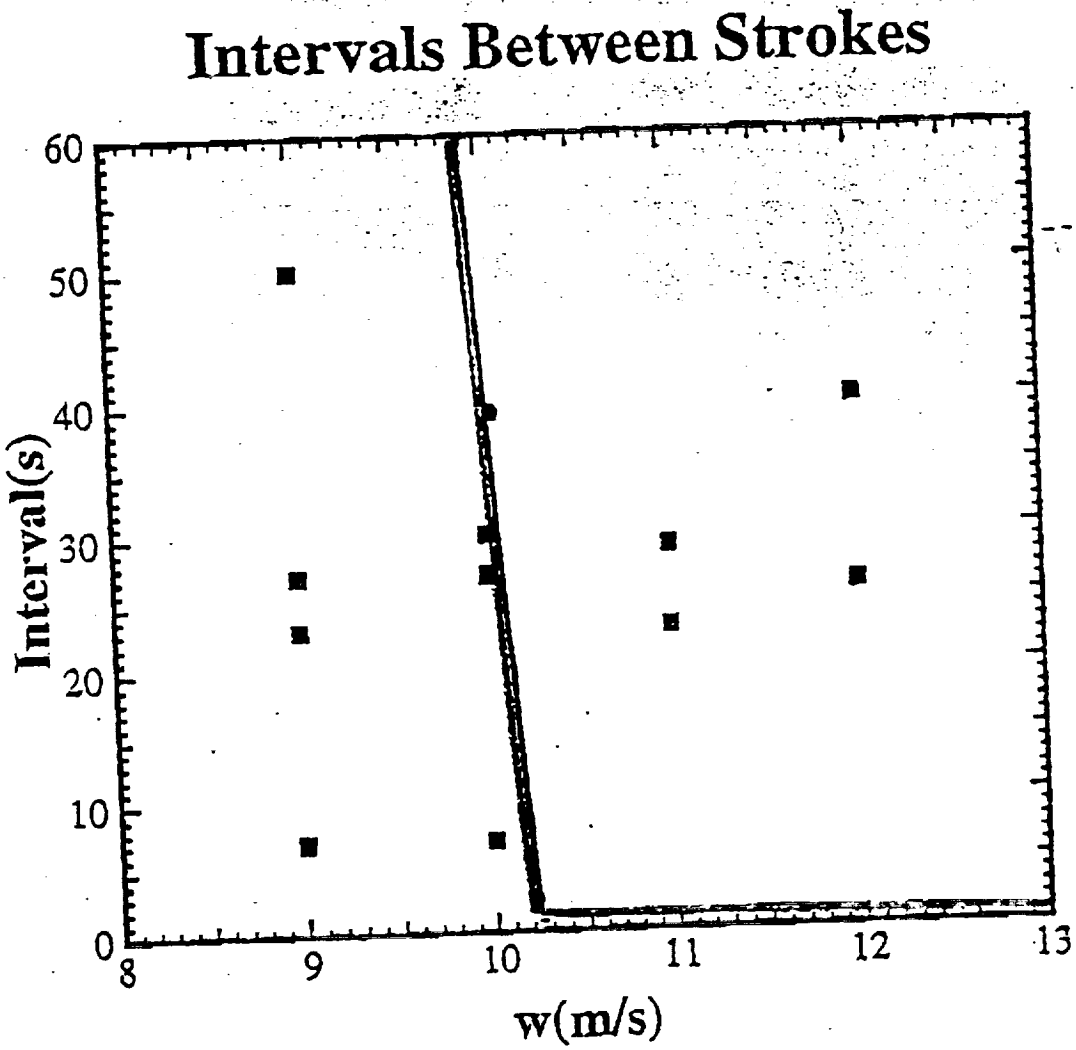
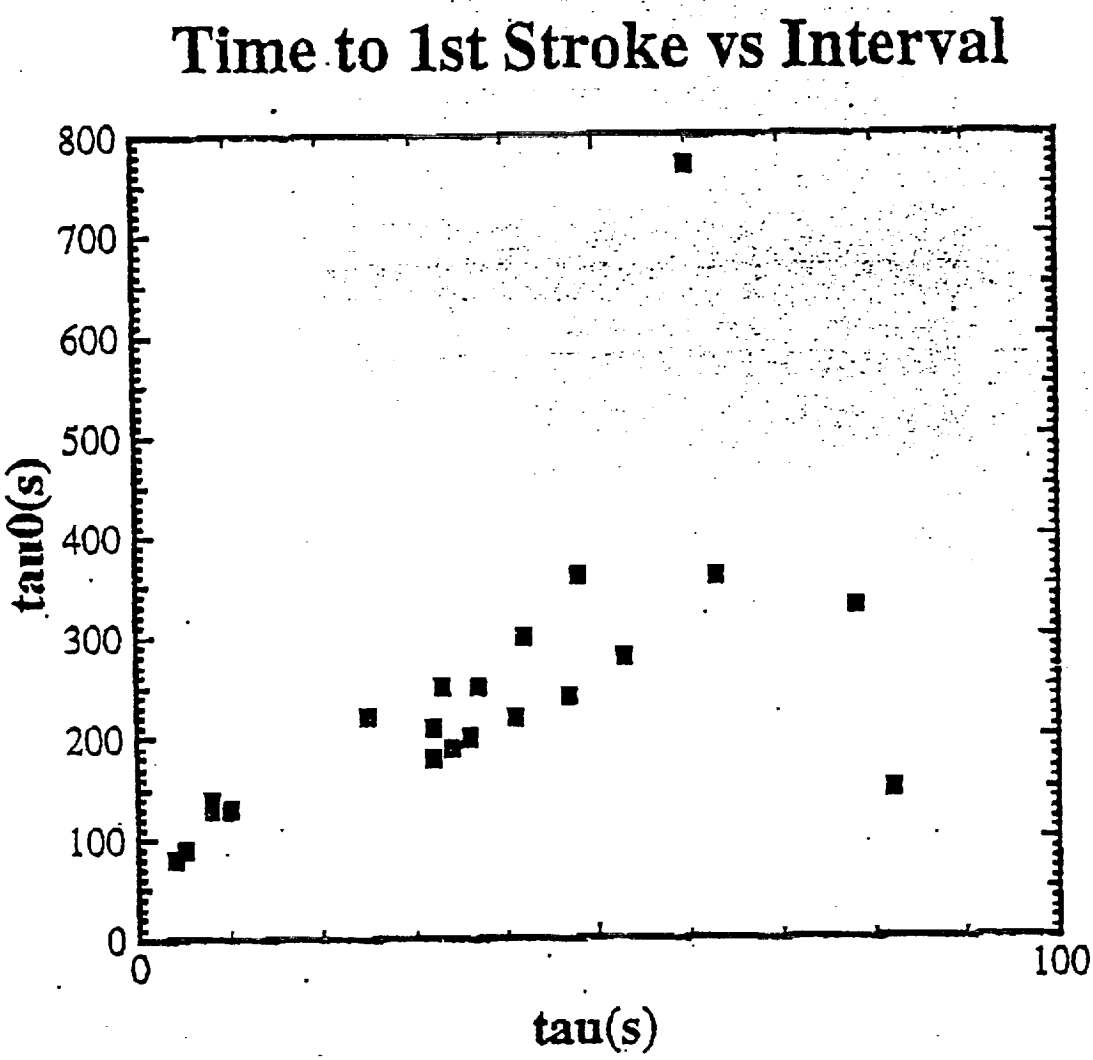
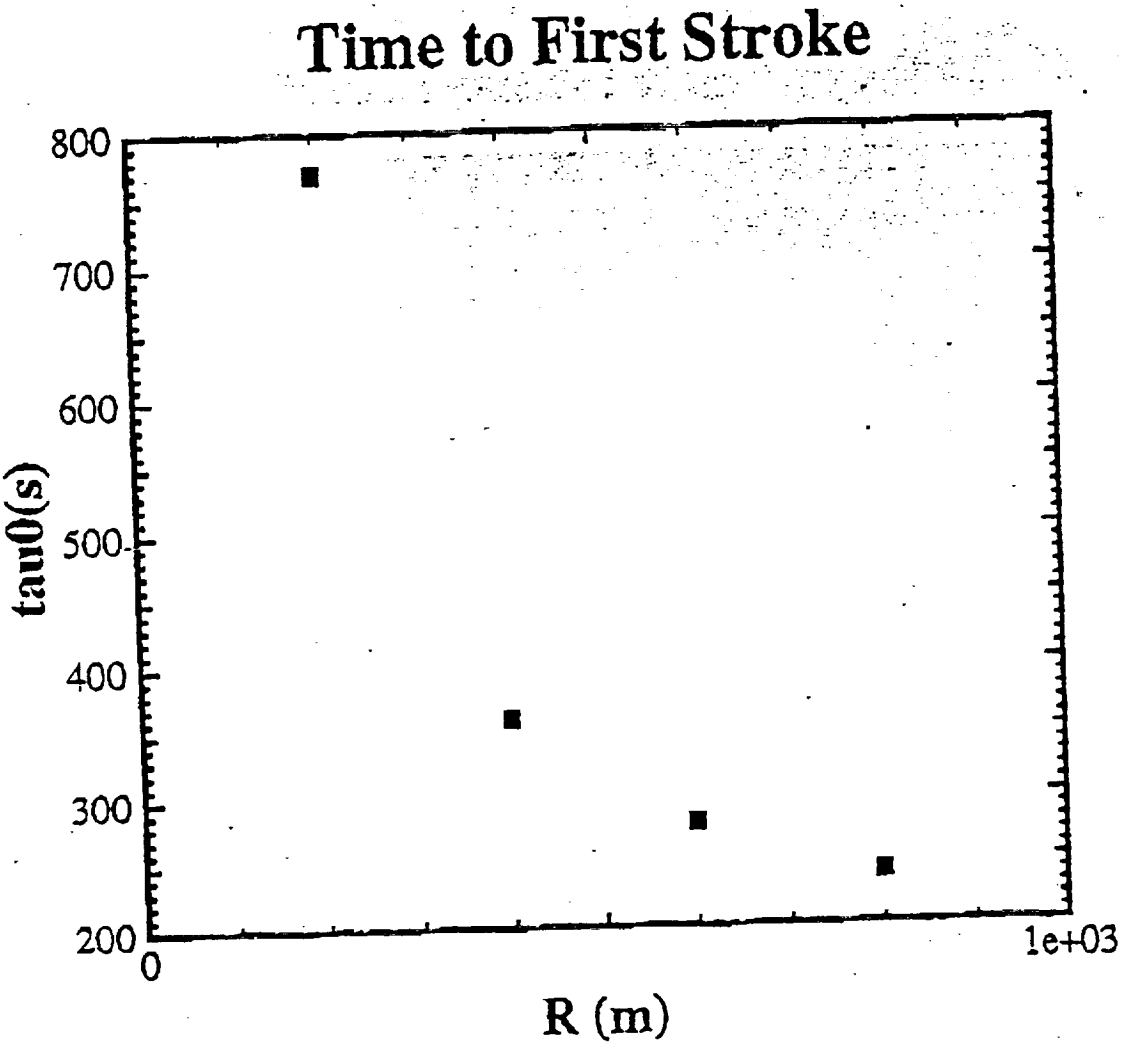
N(m**-3)


Intervals vs Cell Radius
70
60
50
40
tau(s)
0
1e+03
R (m)


Intervals Between Strokes
Interval(s)
60
50
40
30
20
10
0
8
9
10
11
12
13
w(m/s)


Time to 1st Stroke vs Interval
800
700
600
500
400
300
200
100
0
tau0(s)
0
100
tau(s)


Time to First Stroke
800
700
600
500
400
300
200
tau0(s)
0
1e+03
R (m)

APPENDIX 5

THE NASA/USRA COOPERATIVE UNIVERSITY-BASED PROGRAM IN EARTH SYSTEM SCIENCE EDUCATION

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1. BACKGROUND

For the interdisciplinary approach to earth system science to succeed, scientific collaboration must be stimulated both in the classroom and in the laboratory among scientists and departments within universities, among universities, and between university and government science communities. Recognizing this need, two years ago the Universities Space Research Association (USRA) and the National Aeronautics and Space Administration inaugurated the University-based Cooperative Program in Earth System Science Education (ESSE) to serve as a catalyst for the establishment of interdisciplinary curricula in earth system science at universities.

The ESSE program links faculty from twenty-two U.S. universities with one another and with NASA scientists in the development of undergraduate curricula in earth system science. The objectives of the program are to accelerate the establishment of a nation wide academic forum for earth system and global change science, and to expand the interdisciplinary interests and number of future scientists who elect to pursue earth science research professionally. The program offers financial incentives to universities that are willing to participate cooperatively with other universities and NASA in curriculum development within a framework designed to overcome traditional barriers to interdisciplinary science education.

2. PROGRAM DESCRIPTION

Under the ESSE program, each participating university is required to develop and offer a survey course and a senior level course. In these courses, students are introduced to integrated earth systems concepts. The broad objectives of both courses are to instill an appreciation of the social, economic and political implications of global change, and knowledge of the earth's physical climate and ecological systems. Students benefit from interaction with faculty from various disciplines within a university, visiting faculty from other universities and visiting NASA scientists.

An objective of the survey level course is to reach the larger general student body regarding current issues in global change and provide them with scientific basis of the earth system appropriate to an elective course that fulfills undergraduate science requirements. Embodied in this objective is the aim to raise the level of appreciation of the challenges that society faces in meeting the issue of global change and ultimately substainable development.

An objective of the senior level course is to provide advanced undergraduate students with the scientific basis of earth system science and challenge them with the scientific pursuit of the many outstanding problems. The emphasis is on the application of advanced concepts and the development of models in a problem-solving, project oriented environment. In this course students from different academic departments work in teams to study and develop conceptual and computer models of physical, chemical, and biological processes of the earth system. The senior course is taught by faculty members

from at least two relevant academic departments, and focuses on scientific problems and issues that are at the interface between two disciplines. Embodied in the objective of the advanced senior-level course is the aim to motivate students with solid foundations in the sciences and mathematics in the study of earth system science, either immediately in the pursuit of graduate studies, or eventually through bringing the strength of disciplinary studies to this area of endeavor.

As part of the broader program, universities participate in an organized exchange of scientists and faculty, in which visiting faculty and scientists from other participating universities and from NASA are invited to bring to the class-room, expertise and perspectives different from those at the host campus.

A principal faculty coordinator (PI) has primary responsibility for conducting and coordinating the activity within the university. This person identifies faculty and other university scientists for teaching the required courses and for potential travel to other universities. He also hosts visiting faculty and scientists from other universities and NASA.

The program facilitates these interactions by providing logistical and travel support directly to scientists from participating universities to visit other universities to guest-lecture in the undergraduate classes, present at least one scientific seminar, and hold discussions with faculty, staff, students and administrators. In coordinating this exchange during an academic year, each university is encouraged to invite at program expense, three scientists from the other universities. NASA-based scientists are also asked to participate in the guest lecturing effort.

One aim of the program is to build stronger NASA-University connections. Each principal faculty participant is asked to establish a working relationship with a NASA-based scientific colleague as a "NASA Affiliate" who is willing to contribute informally to the university's academic program through advising on earth system science class projects and experiments relevant to NASA missions. The NASA affiliate scientist also facilitates access to NASA data, technical material and other resources appropriate for use in the undergraduate courses. Each summer, the principal faculty coordinator and a teaching assistant have the opportunity to spend up to two weeks at a NASA center working with their NASA affiliate scientist to identify scientific problems of importance to NASA, and to identify resources that could be made available for classroom use. In many cases the NASA affiliate scientist visits the university for several days during each academic year as a guest lecturer.

The principal faculty participants from the universities also contribute to the overall direction of the program through collective efforts. The participants meet twice annually as a steering committee to discuss approaches and common problems to the development of course content, instructional materials, laboratory exercises, and the development of interdisciplinary earth science programs at their universities. Faculty also plan for the inter-university visitor exchange at these meetings, and explore broader issues and strategies for development of degree programs in earth system science within universities.

In addition to these regular meetings, the ESSE program sponsors workshops for TA's and faculty on topics related to the development and exchange of earth system science instructional materials and models.

3. UNIVERSITY PARTICIPATION

The twenty-two universities in the ESSE Program were competitively selected over two years ago to participate in this five-year effort. The selections were based on the strength of proposals addressing the interdisciplinary strength of existing programs, faculty and resources, and institutional commitment to

development of interdisciplinary earth science curricula. Considerations of a scientific balance among proposed university programs ensured a diversity of disciplines that provided a basis for inter-university collaboration. The universities participating in this initial five year effort are:

University of Alaska-Fairbanks
University of Arizona
Univ. of California Santa Barbara
Univ. of California Los Angeles
Johns Hopkins University
University of New Hampshire
Ohio State University
Pennsylvania State University
Rice University
Utah State University
University of Wisconsin-Madison
University of Alabama-Huntsville
University of Iowa
University of Florida
University of Minnesota
New York University
Northwestern University
Princeton University
Purdue University
Rutgers University
Stanford University
Washington University

Although the course organization and teaching format varies widely from university to university, the survey courses are typically taught by two or more faculty members. As intended under this program, the senior courses are also being taught by faculty from two or more departments and/or disciplines, and guest lecturers. The departments and academic programs involved in these courses covers a wide range of disciplines. Among the various universities they include:

Agricultural and Irrigation Engr.
Atmospheric and Oceanic Sciences
Biological Sciences
Chemical-Biochemical Engineering
Civil & Environmental Engineering
Economics
Earth and Space Science
Earth and Planetary Sciences
Ecology and Evolutionary Biology
Forest Resources
Geography
Geology and Geophysics
Geosciences
Marine Science
Meteorology
Physiology and Biophysics
Physics
Plant, Soils, and Biometeorology
Space Physics and Astronomy
Soil and Water Sciences
Tree-Ring Research

In addition to offering the required courses and various exchange activities described above, each university in the program is expected to complement the ESSE funded activities program with related activities (e.g., seminar series) and supplemental resources as evidence of commitment to the program.

All universities in the program participate in all meeting and travel/exchange activities. Within a four year period, each university receives two years of direct support at a level of $25,000 per year to be used by the institution in ways appropriate to the institution's unique needs, while consistent with the overall program objectives and guidelines. Direct program funds are primarily used for activities that are in support of classroom instruction, e.g., TA support, preparation of instructional materials, and development of innovative methods for teaching earth system science topics and concepts. Another $10,000/year is allocated for each school within the program over a four year period. This allocation provides travel support for the required university exchange and semi-annual meetings for principal faculty participants as a steering committee. The two year periods of direct full stipend support are staggered in time among the universities for both programming and budgetary reasons.

4. STATUS SUMMARY

Thirteen universities received full stipend support under during the 1992-93 academic year. The travel funds, which support faculty exchange, travel to NASA centers, and attendance by participating

faculty at steering meetings, were provided to all twenty-two universities in the program during the 92-93 and 93-94 academic years.

Total ESSE survey course enrollment during the 1992-93 academic year was 1,679 and ESSE senior course enrollment was 518. As intended, enrollment in the survey courses was dominated by freshman and sophomore non-science majors. The senior course enrollments were mainly comprised of science majors and upperclassmen, with some participation by graduate students. The average survey class size in the 92-93 academic year was 84, and 29 in the senior courses.

Seventeen schools are offering courses with direct ESSE support in the 1993-1994 academic year. Of these, seven schools will be offering the courses for the first time under ESSE. AY 93-94 enrollments of approximately 2500 and 600 are expected at the survey level and senior levels respectively, not including the universities teaching their courses but no longer receiving the direct full stipend support. During the next two years, the projected total enrollments in courses developed with support from the ESSE program will approach 3,000 students at the survey level, and 1,000 students at the senior level.

5. DIRECTIONS AND PLANS

The steering committee meetings of principal faculty participants for this program provide a forum for addressing a number of important and longer range issues such as establishment of a joint activity for exchange of course and text materials, development of degree programs in Earth System Science, and identifying mechanisms and strategies for further enhancing direct government/university scientific exchange. Steering meetings were held in October 1991 near NASA Headquarters, June 1992 near NASA Goddard, December 1992 at Stanford University, and in June 1993 at NASA Langley in Hampton VA.

Among the emerging special interests of this group are the utilization of computer aided learning and computer technology in the instructional environment. In addition to the steering meetings, a three-day workshop on "Modeling in the Classroom" was held in July 1992. This workshop involved training faculty and teaching assistants from all twenty-two ESSE universities on the use of STELLA system modeling software. A workshop involving ESSE faculty and teaching assistants is planned for the coming academic year on classroom implementation of the "Geoscope - Global Change Encyclopedia". The workshop will be jointly sponsored by NASA and the Canadian Space Agency, which produced Geoscope for the International Space Year. "Geoscope" is a PC-based, CD-ROM driven interactive system that facilitates display and analysis of earth science data in concert with instructional text, glossaries and socioeconomic data bases. These workshops under the ESSE program encourage more widespread use of instructional materials and models of earth system science generated with these software systems.

A future aim is to engage broader university participation in ESSE through direct involvement and by making materials produced by ESSE participants available for wider use. Plans are being formulated to extend the program with continued funding through NASA with possibly additional support from other government agencies involved with the U.S. Global Change Research Program. The hope is to be able to issue a request for proposals during the coming academic year in order to bring more universities into the Cooperative University-based Program in Earth System Science Education.

6. ACKNOWLEDGEMENTS

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